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.

[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 Dec. 1, 2016. Published January 2017. Originally approved in 2002. Last previous edition approved in 2014 as D6760 – 14. DOI: 10.1520/D6760-16.

[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.

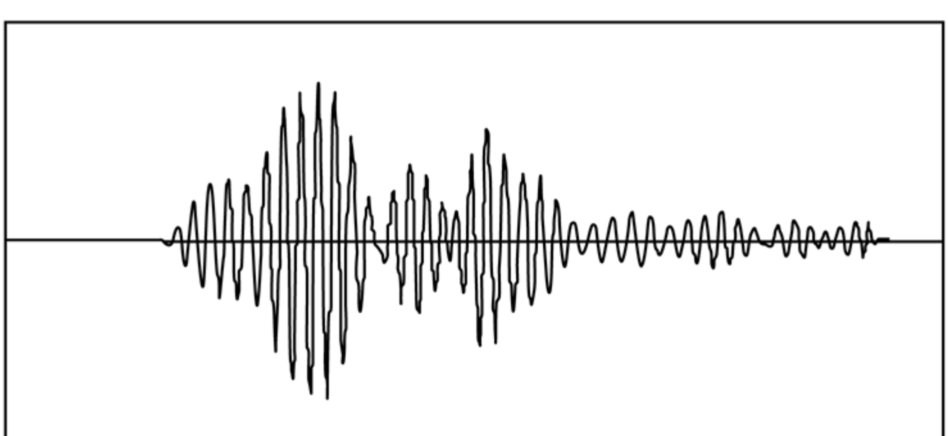

FIG. 1 An Ultrasonic Pulse from Receiver

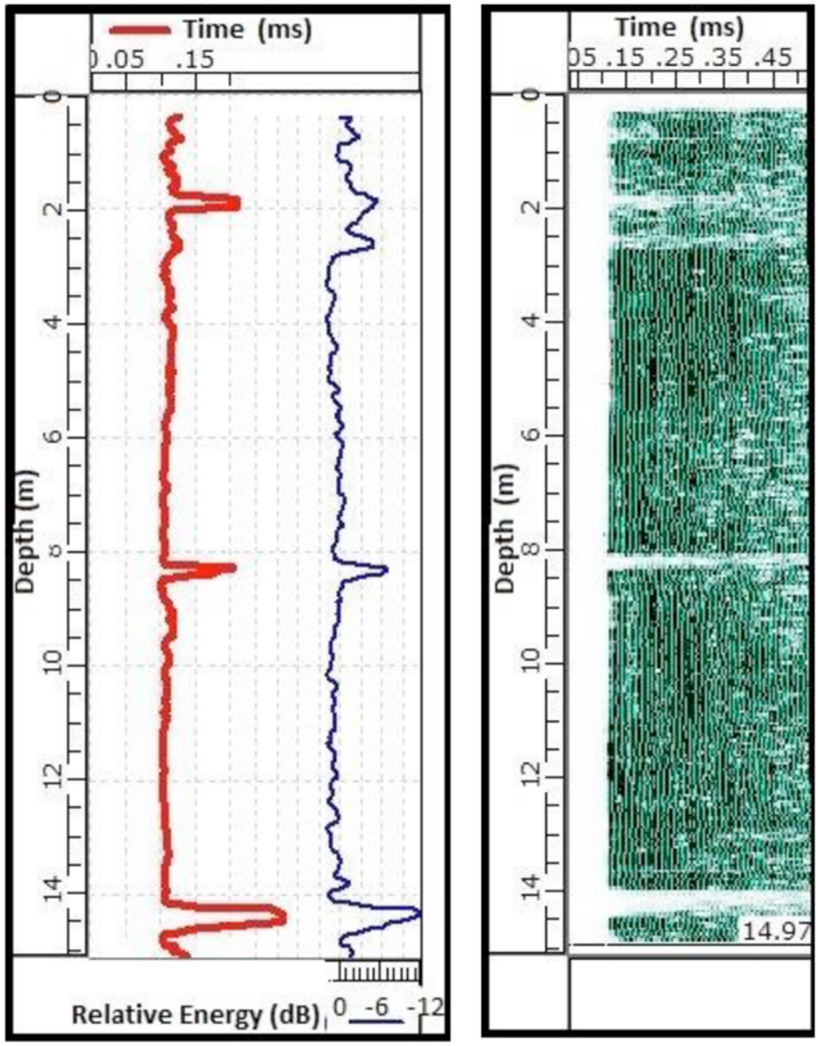

FIG. 2 Typical Ultrasonic Profile

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 ducts can be labeled based on the site plan, structure orientation or other methods to document access duct designations assigned and used for reporting test results.

6.3 *Apparatus for Obtaining Measurements:*

6.3.1 *Probes—*Probes shall allow a generated or detected pulse within 125 mm of the bottom of the access duct. The weight of each probe shall in all cases be sufficient to allow it to sink under its own weight in the access ducts. The probe housing shall be waterproof to at least 1.5 times the maximum depth of testing.

6.3.2 *Transmitter Probe—*The transmitter probe shall generate an ultrasonic pulse with a frequency of between 30,000 Hz and 60,000 Hz.

6.3.3 *Receiver Probe—*The receiver probe shall be of a similar size and compatible design to the transmitter probe and used to detect the arrival of the ultrasonic pulse generated by the transmitter probe.

6.3.4 *Probe Centralizer—*If the receiver or transmitter probes, or both, are less than half the access duct diameter, each probe shall be fitted with centralizers with effective diameter equivalent to at least 50 % of the access duct diameter. It shall be designed to minimize any possible snagging on irregularities in the inner access duct wall.

6.3.5 *Signal Transmission Cables—*The signal cables used to deploy the probes and transmit data from the probes shall be sufficiently robust to support the probes' weight. The cable shall be abrasion resistant to allow repeated field use and maintain flexibility in the range of anticipated temperatures. All cable connectors or splices, if any, shall be watertight. Where the signal transmission cables exit the access duct, suitable cable guides, pulleys or cushioning material shall be fitted inside the access ducts to minimize abrasion and generally assist with smooth deployment of the probes.

6.3.6 *Probe Depth-Measuring Device—*The signal cables shall be passed over or through a pulley with a depth-encoding device to determine the depth to the location of the transmitter and receiver on the probes in the access ducts throughout the test. The design of the depth-measuring device shall be such that cable slippage shall not occur. Preferably a separate depth-measuring device shall monitor each probe so the exact depth of each probe is known at all times. (Alternately a single pulley can be connected to one electronic depth encoder, but then the probes must remain at the same known relative elevation difference for the entire test.) The depth-measuring device shall be accurate to within 1 % of the access duct length, or 0.25 m, whichever is larger.

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

6.4.1 *General—*The signals from the transmitter and receiver probes and the depth-measuring device shall be transmitted to a field rugged, computerized apparatus for recording, processing and displaying the data in the form of an ultrasonic profile. A typical schematic arrangement for the test apparatus is illustrated in Fig. 3. The apparatus shall generate pulses from the transmitter probe either at fixed depth intervals or at fixed time intervals. In the latter case, the depth shall be recorded and assigned to each pulse captured by the apparatus for the instant of pulse generation. The rate of pulse generation by either method shall generate at least one ultrasonic pulse for every required depth interval, typically 50 mm or less. The apparatus shall have adjustable gain to optimize detection of the transmitted pulse by the receiver probe for the concrete under test.

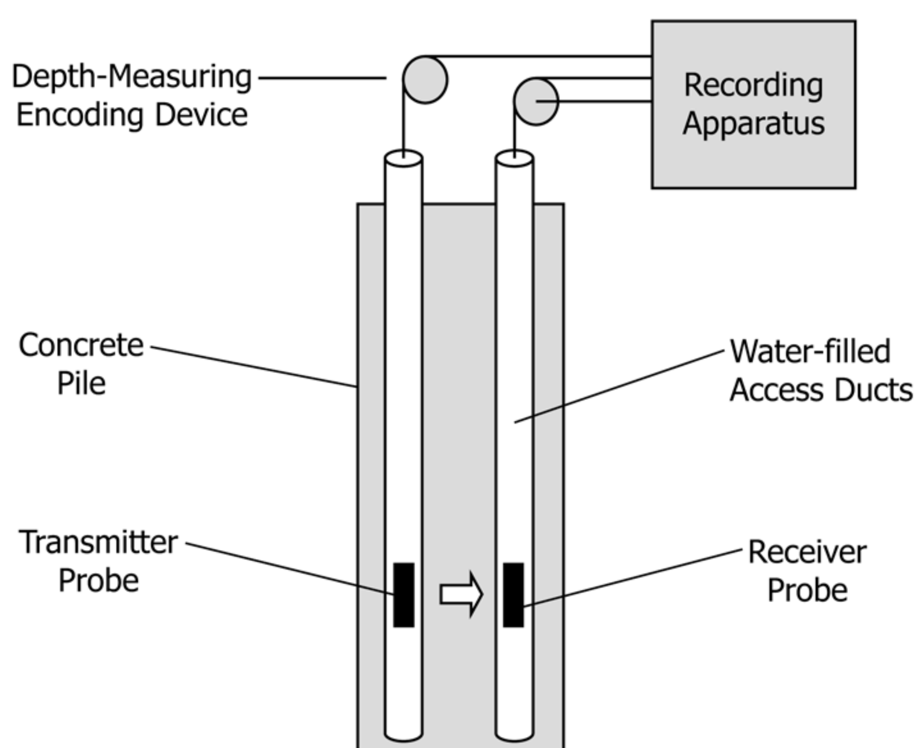

FIG. 3 Test Arrangement

6.4.2 *Recording Apparatus*—Each transmitted ultrasonic pulse shall immediately start the data acquisition for the receiver probe. Analog signals of an ultrasonic pulse measured by the receiving probe shall be digitized by an analog to digital converter with a minimum amplitude resolution of 12 bits and a minimum sampling frequency of 250,000 Hz. The apparatus shall read the depth-measuring device and assign a depth to each digitized ultrasonic pulse. The apparatus shall store these raw digitized ultrasonic pulses and the processed data from each ultrasonic profile for each pair of access ducts. All stored data shall have identifying header information attached to it describing the test location, deep foundation element and ultrasonic profile identifier, date stamp and all pertinent information regarding the test.

6.4.3 *Apparatus for Processing Data*—The apparatus for processing the data shall be a digital computer capable of analyzing all data to identify at least the First Arrival Time and Relative Energy of the transmitted ultrasonic pulse at the receiver probe for each depth interval. The data shall then be compiled into a single ultrasonic profile for each access duct pair.

6.4.4 *Apparatus for Display of Measured Data*—The apparatus shall be capable of displaying the raw receiver ultrasonic pulses to confirm data quality during acquisition. After data acquisition, the apparatus shall be capable of displaying the raw data of each ultrasonic pulse along the entire pile length. The apparatus shall also display the processed ultrasonic profile.

7. Procedure

7.1 *Installation of Preformed Access Ducts:*

7.1.1 *General*—The access ducts shall be supplied and installed during construction by or in cooperation with the contractor of the deep foundation element to be tested. The total number of installed access ducts in the deep foundation element should be chosen consistent with good coverage of the cross-section. As a guide for cylindrical deep foundations, the number of access ducts is often selected as one access duct for every 0.25 to 0.30 m of deep foundation element diameter, with a minimum of three and a maximum of eight access ducts, spaced equally around the circumference. However, a single access duct, constructed of a material such as PVC that has a wave speed less than the deep foundation element, is required for single-hole testing of deep foundation elements with a diameter of about 0.5 m or less. For walls and barrettes, the distance between access ducts is typically between 1 and 1.5 metres. Typical access duct layout configurations for various structural elements are illustrated in Fig. 4.

7.1.2 *Preformed Access Duct Preparation*—The access ducts shall be straight and free from internal obstructions. The exterior tube surface shall be free from contamination (for example, oil, dirt, loose rust, mill scale, etc.), and for plastic tubes the surface shall be fully roughened by abrasion prior to installation, to ensure a good bond between the tube surface and the surrounding concrete. The ends of the access ducts shall be undamaged and suitably prepared for the end caps and coupling system adopted. The access ducts shall be close-ended at the bottom and fitted with removable end caps at the top to prevent entry of concrete or foreign objects, which could block the tubes prior to testing operations.

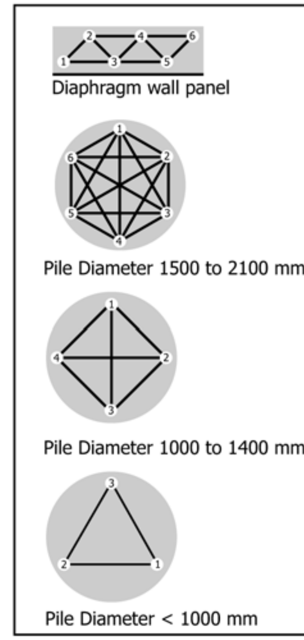

FIG. 4 Typical Access Duct Configurations

7.1.3 *Preformed Access Duct Extensions*—If extension of the access ducts is necessary due to large lengths, access tube couplings shall be used, which prevent slurry or grout ingress during construction. Butt welding for steel tube couplings shall not be permitted. For coupling plastic tubes, threaded or glued plastic couplings shall be used. Wrapping the joints with tape or other compounds is strictly forbidden.

7.2 *Preformed Access Duct Installation*—The access ducts shall be installed such that their bottom is as close as possible to the bottom of the concrete deep foundation element so that the bottom condition can be tested. The access ducts shall have a minimum concrete cover of one tube diameter. Access tubes shall be secured to the inside of the main axial reinforcement of the steel cage at frequent and regular intervals along their length to maintain the tube alignment during cage lifting, lowering and subsequent concreting of the deep foundation element. During tube installation, care should be taken to ensure that all access tubes are as parallel to each other as possible. After installation of the reinforcement cage into the deep foundation element, the top end caps shall be temporarily removed and the tubes shall be inspected to verify they are clear of obstructions. Access ducts shall preferably be filled with water prior to, or within one hour of, concrete placement to assure good bonding of the concrete to the tube after the concrete cools.

7.2.1 *Preformed Access Duct Installation Records*—Lengths of each access tube and separation of the access tubes at the top and bottom, and preferably at the midpoint along the length shall be recorded to the nearest 10 mm. Joint details and their nominal position shall be recorded. Records of the access duct installation details shall be made and kept by the organization installing the access ducts.

7.3 *Installation of Drilled Access Ducts (Boreholes)*—In cases where structures to be tested have no preformed access tubes, drilled boreholes may be used to provide probe access. Normal procedures for concrete drilling or coring, or both, can be used to form the access ducts, selecting a borehole diameter consistent with the probes and drilling equipment capable of drilling an essentially straight borehole. Where critical, the alignment of each borehole can be checked by independent means. The borehole cores shall be inspected for additional insight.

7.4 *General Test Procedures:*

7.4.1 Check that the apparatus is functioning correctly prior to mobilizing to site.

7.4.2 *Date of Testing*—The tests shall be performed no sooner than 3 to 7 days after casting depending on concrete strength and shaft diameter (larger diameter shafts may take closer to 7 days) unless agreed with the specifier. In the case of plastic access tubes, testing should be completed as soon as practical to prevent loss of data caused by debonding of the concrete from the tube.

7.4.3 *Preparing Access Ducts for Testing*—The access ducts shall be exposed and the protective top caps removed. Preferably, use a weighted measuring tape to measure and record the length of each access duct to the nearest 100 mm. If the access duct is blocked, record the depth of the blockage from the access duct top. The access ducts shall be filled to the top with clean water.

7.4.4 *Access Duct Documentation*—Assign a systematic reference label to each access duct and prepare a reference sketch of the access duct layout using the magnetic compass or a site plan diagram. The as-built details of the access duct layout shall be recorded including measuring the center-to-center separations of the exposed access ducts to the nearest 10 mm using a measuring tape and measuring the access duct length exposed above the concrete, if any, to the nearest 10 mm.

7.4.5 *Probe Preparation*—To obtain a good acoustic coupling between the probes and the water in the access ducts, the probes shall be clean and free from all contaminants.

7.4.6 The functionality of the equipment should be checked according to the manufacturer's operation instructions. Check that test equipment and probes are functioning correctly prior to actual testing by verifying that ultrasonic pulses are received in the recording apparatus.

7.5 *Obtaining Measurements with the Apparatus (Cross hole):*

7.5.1 Pay due regard to safety and any special instructions or manufacturer's procedures pertaining to the particular apparatus employed.

7.5.2 Document the pair of access ducts being tested. Attach the probe cable guides to the access ducts. Insert the transmitter and receiver probes into these access ducts ensuring that the cables are engaged over the respective cable guides fixed at the access duct tops. If the access duct tops are not level, then hold the probes at the level of the lower access duct top.

7.5.3 Carefully lower the probes down to the bottom of the access ducts, always keeping them at approximately the same level, until one probe reaches the bottom of the duct or encounters an obstruction (for example, because one access duct is shorter, bent or blocked). Set the depth location to the bottom of the access ducts. Raise the probes from the bottom of the access ducts to a portion of the deep foundation element with good quality concrete. If required by the test system manufacturer, to ensure that the distance between probes is minimized, the relative level of the probes should be adjusted until the first arrival of the signal is minimized. Temporarily secure the cables at that level with the cables remaining in equal tension.

7.5.4 Adjust the test apparatus, if necessary, selecting the transmitter power setting and receiver gain required for the access duct separation distance and concrete characteristics encountered such that an ultrasonic pulse with good amplitude can be consistently obtained in a portion of deep foundation element of good quality. Return the probes to the access duct bottoms.

NOTE 2—The deep foundation element top and bottom are more likely to contain contaminated concrete than at intermediate locations. Setting the signal conditioning gains should be done at an intermediate location along the element length. The gain settings may be manually or automatically adjusted (as per apparatus system used) to adapt to different spacings between tested access duct pairs so that good signal strength is maintained.

7.5.5 Begin recording the ultrasonic pulses as the probes are raised. Lift both probes by steadily pulling the probe cables simultaneously at a speed of ascent slow enough to capture one ultrasonic pulse for each depth interval specified. If an ultrasonic pulse is not obtained for any depth interval, then the probes shall be lowered past that depth and the test repeated until all depth intervals have an associated ultrasonic pulse.

NOTE 3—In some cases it is advantageous to place the probes at different levels during pulling. The differences can be at either fixed or variable distances depending on the application.

7.6 *Obtaining Measurements with the Apparatus (Single hole):*

7.6.1 Pay due regard to safety and any special instructions or manufacturer's procedures pertaining to the particular apparatus employed.

7.6.2 The transmitter and receiver probes shall be fixed to each other at a preset vertical separation (for example, typically 600 mm). The vertical separation may be increased to scan a larger radius around the access duct. This will, however, reduce the measured ultrasonic profile length and the detection resolution. Attach the probe cable guide to the single access duct (PVC or equivalent duct required). Insert the transmitter and receiver probes into this access duct ensuring that the cables are engaged over the cable guide fixed at the access duct top.

7.6.3 Carefully lower the probes down to the bottom of the access ducts, until the lower probe reaches the bottom of the duct or encounters an obstruction. Set the depth location to the bottom of the tubes. Raise the probes from the tube bottom to a portion of the deep foundation element with good quality concrete. Temporarily secure the cables at that level.

7.6.4 Adjust the test apparatus, if necessary, selecting the transmitter power setting and receiver gain required for concrete characteristics encountered such that an ultrasonic pulse with good amplitude can be consistently obtained in a portion of deep foundation element of good quality. Special care should be taken since the faster signal through concrete has significantly lower amplitude than the slower signal through the water-filled tube. Return the probes to the access duct bottom.

7.6.5 Begin recording the ultrasonic pulses as the probes are raised. Lift both probes by steadily pulling the probe cables simultaneously at a speed of ascent slow enough to capture one ultrasonic pulse for each depth interval specified. If an ultrasonic pulse is not obtained for any depth interval, then the probes shall be lowered past that depth and the test repeated until all depth intervals have an associated ultrasonic pulse.

7.7 *Data Quality Checks:*

7.7.1 After completing data acquisition, view the ultrasonic profile obtained. Check the ultrasonic profile quality. The waterfall graphics (4.2, Fig. 2) should be of good resolution and contrast.

7.7.2 Compare the length of the measured ultrasonic profile with the measured access duct length. In comparing these measurements a correction shall be made to account for the length of the probe assembly. The difference between the corrected measurements shall not exceed 1 % of the measured length or 0.25 m, whichever is larger.

7.7.3 Ensure that the captured data are labeled with the deep foundation element identification, identification of the two access ducts for the data set, date of test, identification of the test operator, and any further necessary project information such as site and location details as requested by the specifier. Store the data and information safely.

7.8 *Completing the Test:*

7.8.1 If the ultrasonic profile indicates an anomaly, then the suspect anomaly zone may be further investigated by special test procedures such as fan shaped tests, tests with the probes raised at a fixed offset distance, or other tomographical techniques. The probes shall be lowered to a depth of at least 1 m below the anomaly and raised to a depth of at least 1 m above the anomaly.

7.8.2 Repeat 7.5 – 7.8 for the remaining pairs of access ducts.

NOTE 4—If specified, the access ducts may be grouted upon completion of the testing.

7.9 *Analysis of Measurements:*

7.9.1 The results of the analysis shall include the First Arrival Time (FAT) of the ultrasonic pulses and the Relative Energy (RE) plotted relative to the deep foundation element depth. Due to the large number of pulses in a single ultrasonic profile First Arrival Time is usually determined by a suitable algorithm. FAT values incorrectly determined by the algorithm, such as caused by a noise spike for a single data point, shall be corrected manually. The energy E of a given pulse is found by summing the absolute values of the pulse amplitudes (Fig. 1) for at least five cycles starting from FAT. The Relative Energy (RE) of a given pulse is given by:

$$RE_{(dB)} = 20 \log(E/E_0) \quad (1)$$

Where the constant E_0 is a reference energy. The Relative Energy is presented on a linear dB scale. Fig. 2 illustrates the processed signals on the left with the traditional "waterfall" diagram shown on the right. These data show a special test shaft with purposely-installed anomalies at depths of 1.8, 8.2 and 14.2 m below the top of the access ducts, showing both First Arrival Time increase and Relative Energy decrease at each anomaly location.

7.9.2 Filtering or smoothing of the processed results shall be kept to an absolute minimum since excessive smoothing or filtering can hide flaws and thus lead to improper interpretation of results. Therefore, if any post processing filtering or smoothing of the data is performed for the processed results, then the amount of smoothing or filtering shall be shown and the waterfall diagram must also be presented in the report.

7.9.3 The original unfiltered data shall be kept permanently and be accessible if requested for a possible future review.

NOTE 5—It is recommended that the waterfall diagram (which is a nesting of ultrasonic pulses in an ultrasonic profile) be included in the data presentation.

7.9.4 Any further 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 must contain proper engineering judgment and experience. Any evaluation of integrity is to be made by an engineer with specialized experience in this field, and is beyond the scope of this test method.

8. Report: Test Data Sheet(s)/Form(s)

8.1 The methodology used to specify how data are recorded, as given below, is covered in Section 7.

8.2 Record as a minimum the following general information when available or applicable:

8.2.1 Identification of testing agency,

8.2.2 Project and client identification,

8.2.3 Date of test,

8.2.4 Description of the testing apparatus unit and probes, and

8.2.5 Identification of test staff and of person responsible for the validity of the test records.

8.3 Record as a minimum the test deep foundation data - when available or applicable:

8.3.1 Identification and location of test deep foundation element,

8.3.2 As-built geometry of test deep foundation element including nominal or actual (or both) diameter to the nearest 10 mm and length to the nearest 100 mm,

8.3.3 Test deep foundation element installation method and date, with any specific installation observations,

8.3.4 Arrangement and identification of access ducts, relative separation of ducts to the nearest 10 mm, and identifying designation documentation,

8.3.5 The material and diameter of the access ducts,

8.3.6 Any failure of the probes to penetrate the full depth of the access ducts shall be reported to the nearest 100 mm,

8.3.7 Cut-off and ground elevation of the deep foundation element, to the nearest 100 mm,

8.3.8 Elevation of each access duct top, or length of access duct above top of concrete at time of test to the nearest 10 mm.

8.4 Record as a minimum the following ultrasonic profiles data:

8.4.1 The access ducts for each ultrasonic profile,

8.4.2 The First Arrival Time and the Relative Energy versus depth,

8.4.3 The waterfall diagram.

9. Precision and Bias

9.1 *Precision*—Test data on precision is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site.

9.1.1 The Subcommittee D18.11 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

9.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

10. Keywords

10.1 barrette; bored pile; crosshole sonic logging; crosshole testing; drilled shaft; integrity test; single hole ultrasonic testing; ultrasonic logging; ultrasonic testing