Designation: D7383 – 10

Standard Test Methods for Axial Compressive Force Pulse (Rapid) Testing of Deep Foundations[1]

This standard is issued under the fixed designation D7383; 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 cover procedures for testing an individual vertical or inclined deep foundation to determine the displacement response to an axial compressive force pulse applied at its top. These test methods apply to all deep foundation units, referred to herein as "piles," that function in a manner similar to driven or cast-in-place piles, regardless of their method of installation.

1.2 Two alternative procedures are provided:

1.2.1 Procedure A uses a combustion gas pressure apparatus to produce the required axial compressive force pulse.

1.2.2 Procedure B uses a cushioned drop mass apparatus to produce the required axial compressive force pulse.

1.3 This standard provides minimum requirements for testing deep foundations under an axial compressive force pulse. Plans, specifications, provisions (or combinations thereof) prepared by a qualified engineer, may provide additional requirements and procedures as needed to satisfy the objectives of a particular deep foundation test program. The engineer in responsible charge of the foundation design, referred to herein as the "Engineer," shall approve any deviations, deletions, or additions to the requirements of this standard.

1.4 The proper conduct and evaluation of force pulse testing requires special knowledge and experience. A qualified engineer should directly supervise the acquisition of field data and the interpretation of the test results so as to predict the actual performance and adequacy of deep foundations used in the constructed foundation. A qualified engineer shall approve the apparatus used for applying the force pulse, rigging and hoisting equipment, support frames, templates, and test procedures.

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. The word "shall" indicates a mandatory provision, and the word "should" indicates a recommended or advisory provision. Imperative sentences indicate mandatory provisions.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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 method used to specify how data are collected, calculated or recorded in this standard is not directly related to the accuracy to which the data can be applied in the design or other uses, or both. How one uses the results obtained using this standard is beyond its scope.

1.9 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.

1.10 *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.* Section 7 provides a partial list of specific hazards and precautions.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

[1] These test methods are 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.

D1143 Test Method for Piles Under Static Axial Compressive Load (Withdrawn 2005)[3]
D3689 Test Methods for Deep Foundations Under Static Axial Tensile Load
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations
D6026 Practice for Using Significant Digits in Geotechnical Data
D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms used in this standard, see Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cast-in-place pile, n*—a deep foundation unit made of cement grout or concrete and constructed in its final location, for example, drilled shafts, bored piles, caissons, augercast piles, pressure-injected footings, etc.

3.2.2 *deep foundation, n*—a relatively slender structural element (length greater than width) that transmits some or all of the load it supports to soil or rock well below the ground surface. It may be a driven pile, a cast-in-place pile, or an alternate structural element having a similar function.

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

3.2.3 *driven pile, n*—a deep foundation unit made of preformed material with a predetermined shape and size and typically installed by impact hammering, vibrating, or pushing.

3.2.4 *force pulse, n*—for the purposes of this standard, a "force pulse" shall result in a force-time event similar to Fig. 1, typically reaching a target peak force. The applied force shall exceed the pre-load for a duration time of at least twelve times the test pile length (L) divided by the strain wave speed (c), or $12L/c$. The applied force shall also exceed 50 % of the actual peak force for a minimum duration time of four times L/c. The force pulse shall increase smoothly and continuously to the peak force and then decrease smoothly and continuously. Typical force pulse durations range from 90 to 250 ms.

NOTE 1—A force pulse duration of less that $12L/c$ may be acceptable to the Engineer when using supplemental transducers as described in 5.4.

3.2.5 *pre-load, n*—the load applied to the pile head due to the static weight of the test apparatus prior to the test, possibly negligible depending on the design of the test apparatus.

3.2.6 *target peak force, n*—a pre-determined target value for the desired amplitude of the force pulse as defined by the project requirements. This value should typically exceed the sum of the required ultimate axial compressive static capacity plus the dynamic resistance of the pile by an amount determined by the Engineer based on factors including, but not limited to, pile type, soil type, structural strength of the pile, type of structural load, physical restrictions, or other project requirements (see Section 4).

3.2.7 *wave speed, c, n*—the speed with which a strain wave propagates through a pile. It is a property of the pile composition and is represented herein by c. For one-dimensional wave propagation, c is equal to the square root of Elastic

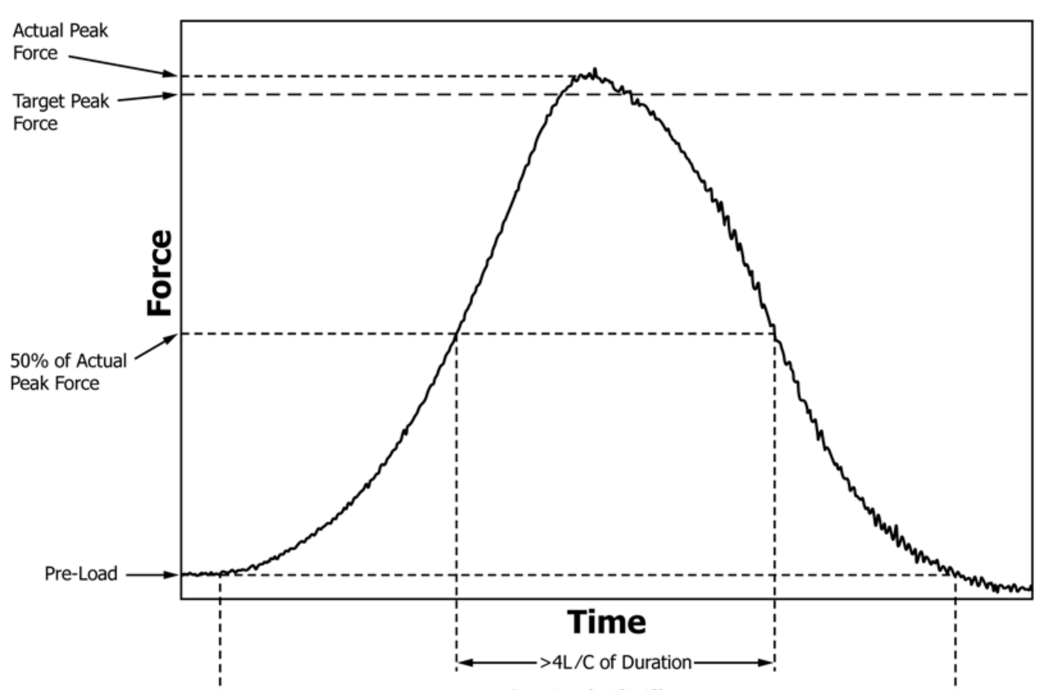

FIG. 1 Typical Axial Compressive Force Pulse

Modulus divided by mass density: $c = (E/\rho)^{1/2}$. Typical values of c are 4000 m/s for concrete piles and 5100 m/s for steel piles.

4. Significance and Use

4.1 Based on the measurements of force and displacement at the pile top, possibly combined with those from acceleration or strain transducers located further down the pile, these test methods measure the pile top deflection in response to an axial compressive force pulse. The relatively long duration of the force pulse compared to the natural period of the test pile causes the pile to compress and translate approximately as a unit during a portion of the pulse, simultaneously mobilizing compressive axial static capacity and dynamic resistance at all points along the length of the pile for that portion of the test. The Engineer may analyze the acquired data using engineering principles and judgment to evaluate the performance of the force pulse apparatus, and the characteristics of the pile's response to the force pulse loading.

4.2 If significant permanent axial movement occurs during the axial force pulse event, the Engineer may analyze the results of the test to estimate, after assessing inertial effects and the dynamic soil and rock response along the side and bottom of the pile, the ultimate axial static compression capacity (see Note 2). The scope of this standard does not include analysis for either ultimate or design foundation capacity. Factors that may affect the axial static capacity estimated from force pulse tests include, but are not limited to, the: *(1)* pile installation equipment and procedures, *(2)* elapsed time since initial installation, *(3)* pile material properties and dimensions, *(4)* type, density, strength, stratification, and saturation of the soil, or rock, or both adjacent to and beneath the pile, *(5)* quality of force pulse test data, *(6)* foundation settlement, *(7)* analysis method, and *(8)* engineering judgment and experience. If the Engineer does not have adequate previous experience with these factors, and with the analysis of force pulse test data, then a static load test carried out according to Test Method D1143 should be used to verify estimates of static capacity and its distribution along the pile length. Test Method D1143 provides a direct and more reliable measurement of static capacity.

NOTE 2—If a force pulse test produces insufficient axial movement, subsequent analysis may overestimate the static capacity because of difficulty in separating the static and dynamic components of the response. The analysis of a force pulse test to estimate static capacity also typically includes a reduction factor to account for the additional load resistance that occurs as a result of a faster rate of loading than used during a static test. Force pulse test results from cohesive soils generally require a greater reduction factor due to the rate of loading effect, chosen conservatively to produce a lower static capacity estimate. The Engineer should determine how the type, size, and shape of the pile, and the properties of the soil or rock beneath and adjacent to the pile, affect the rate-of-loading reduction factors and the amount of movement required to mobilize and accurately assess the static capacity. Correlations between actual measurements and force pulse estimates of the ultimate axial static compression capacity generally improve when using additional transducers embedded in the pile. Static capacity may also change over time after the pile installation, especially for driven piles. Both static and force pulse tests represent the capacity at the time of the respective test, and correlation attempts should provide results for a similar time of testing after pile installation or include analysis to account for changes in the soil strength during the time between the two tests.

4.3 When used in conjunction with additional transducers embedded in the pile, these test methods may also be used to measure the pile response to the axial force pulse along the pile length. When combined with an appropriate method of analysis, the Engineer may use data from these optional transducers to estimate the relative contribution of side shear and end bearing to the mobilized axial static compressive capacity of the pile, or to infer the relative contribution of certain soil layers to the overall axial compressive capacity of the pile.

NOTE 3—When used in conjunction with additional transducers embedded in the pile the force pulse test analysis may provide an estimate of the pile's tension (uplift) capacity. Users of this standard are cautioned to interpret the estimated side resistance conservatively. If the Engineer does not have adequate previous experience for the specific site and pile type with the analysis of force pulse test data for tension capacity, then a static load test carried out according to Test Method D3689 should be used to verify tension capacity estimates. Test Method D3689 provides a direct and more reliable measurement of static tension capacity.

NOTE 4—The quality of the result produced by these test methods 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 these test methods 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. Apparatus

5.1 *General*—Any apparatus capable of applying a force pulse to a pile foundation that is in accordance with Section 3 shall be considered acceptable. The apparatus selected shall be capable of applying a target peak force in accordance with the project requirements. This section describes two specific types of equipment used to generate an axial compressive force pulse: a combustion gas pressure apparatus as shown in Fig. 2 and a cushioned drop-mass apparatus as shown in Fig. 3.

5.2 *Combustion Gas Pressure Apparatus (for Procedure A):*

5.2.1 Piston and cylinder jack capable of confining the operating pressure, and capable of centering the force pulse application to the pile.

5.2.2 Fuel and ignition mechanism to create gas pressure in the combustion chamber.

5.2.3 Reaction beam, supported by cylinder portion of jack to transfer the combustion force to the inertial or other reaction system.

5.2.4 Reaction mass or other means to resist the combustion forces. A reaction mass system will typically weigh between 5 and 15 % of the target peak force and will be comprised of concrete, steel or contained water.

5.2.5 Accumulator or plenum to receive the combustion gas.

5.2.6 Venting apparatus for the release of combustion gas from the plenum.

5.2.7 Silencer apparatus to muffle the noise of the venting combustion gas.

5.2.8 Means or mechanism to protect the pile from damage caused by the fall of the reaction mass system (this will typically consist of a gravel-filled enclosure or a mechanism for arresting the reaction mass such as a hydraulic or mechanical system).

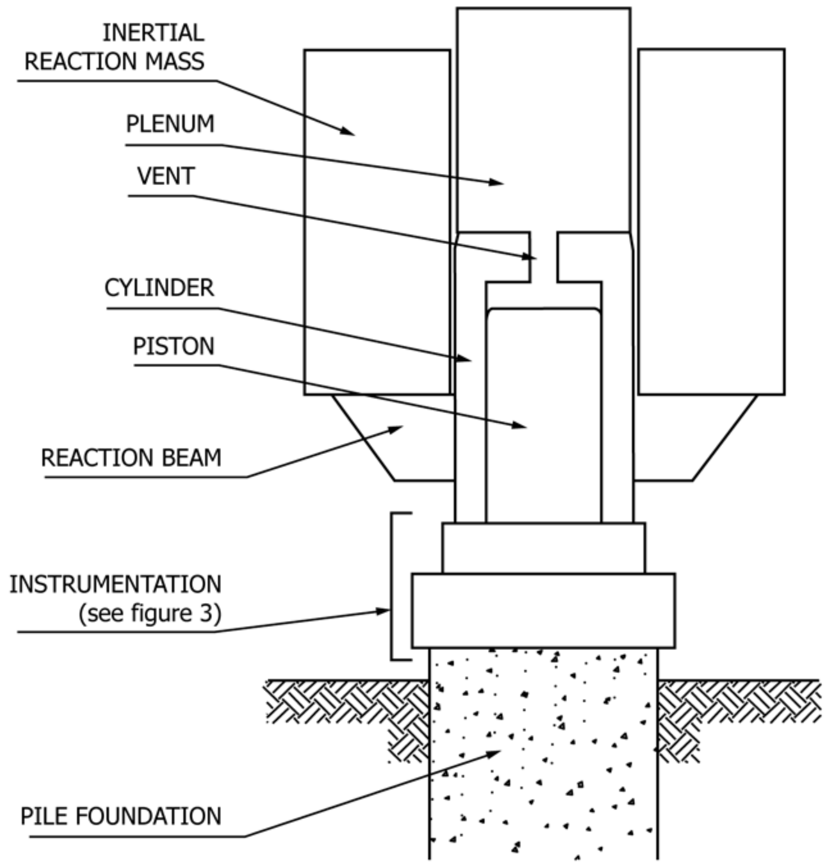

FIG. 2 Schematic of a Combustion Gas Pressure Test Apparatus

5.2.9 Means or mechanism such as a rupture valve or disk to release the combustion gas in the event of an accidental increase in system pressure or malfunction of the system.

5.3 *Cushioned Drop Mass Apparatus (for Procedure B):*

5.3.1 A drop mass comprised of concrete, steel or another material, typically weighing between 5 and 15 % of the target peak force.

5.3.2 A cylinder jack, crane, or winch, capable of lifting the drop mass to the required height.

5.3.3 Release mechanism for the drop mass.

5.3.4 A guiding system for the fall of the drop mass to properly center the force pulse application to the pile.

5.3.5 Springs or cushion material of sufficient strength and stiffness to transfer a force pulse to the test pile.

5.3.6 Optional secondary springs or cushion material to further cushion the force pulse at the beginning and end of the force pulse application.

5.3.7 Optional clamping or catching mechanism on the drop mass, guide system, or lift cylinder to catch the rebounding drop mass after the application of the force pulse, preventing the application of additional force and improving the verification of the permanent pile head displacement by means of an elevation check as described in 6.4.4. This clamping or catching mechanism is preferred but not required.

5.3.8 Accessibility for the measurement of the drop height.

5.3.9 Accumulator or plenum to receive the hydraulic fluids used to raise and to catch the drop mass.

5.4 *Force and Displacement Measurements:*

5.4.1 The apparatus for measuring the force pulse applied to the pile shall consist of a calibrated force transducer mounted directly between the test apparatus and the pile head and in alignment with the central longitudinal axis of the test pile. The force transducer shall have a rated service capacity at least 10 % greater than the target peak force and shall be calibrated to a minimum of the target peak force plus 10 %. The force transducer shall be calibrated to an accuracy of 2 % throughout the applicable measurement range. Calibration of the force transducer shall demonstrate linearity to within 2 %. Hysterisis shall not exceed 2 %. The force transducer shall have a response time of less than 0.1 ms.

5.4.2 The primary apparatus for measuring the axial displacement at the pile head shall consist of a calibrated displacement transducer(s). The device shall be capable of measuring displacements directly and continuously over a range of not less than the larger of: *(a)* 50 mm plus the theoretical elastic shortening of the pile; or *(b)* $D/20$ plus the theoretical elastic shortening of the pile, where D is the pile diameter. The transducer shall have a precision of at least 0.25 mm and a response time of less than 0.1 ms. The transducer shall be calibrated to an accuracy of 2 % throughout the applicable measurement range. The displacement transducer shall be positioned at and parallel to the central longitudinal axis of the pile. If a single transducer cannot be located at the central axis, then position two or more transducers parallel to

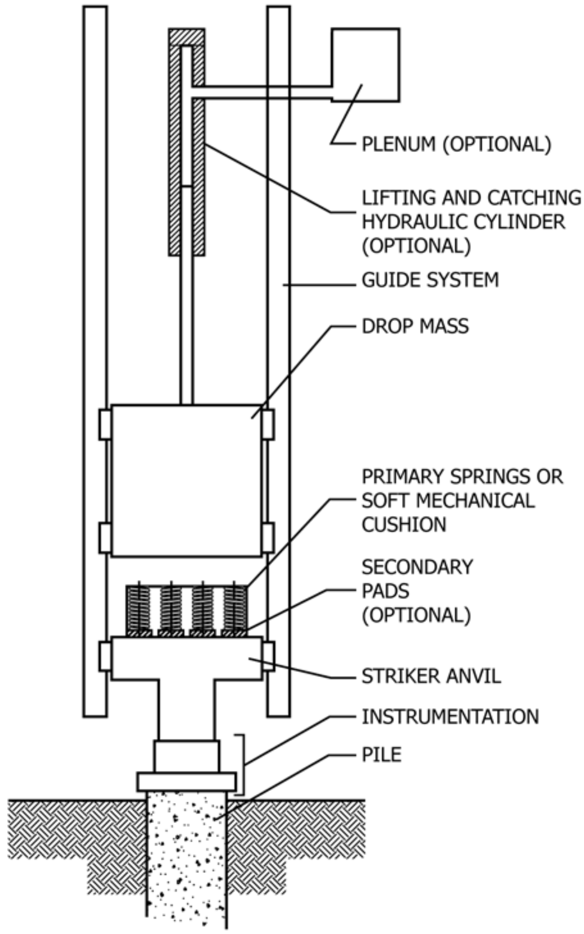

FIG. 3 Schematic of a Cushioned Drop Mass Test Apparatus

and at symmetrical locations with respect to the central longitudinal axis so that the average of their measurements cancels the rotational movement of the pile head. The displacement shall be measured using a stationary reference, such as shown in Fig. 4. Position the displacement reference at a sufficient distance from the test pile such that the measurements are not influenced by test-induced disturbances (typically 20 to 30 m), considering the expected force pulse duration and wave speed in the surrounding soil and surface material.

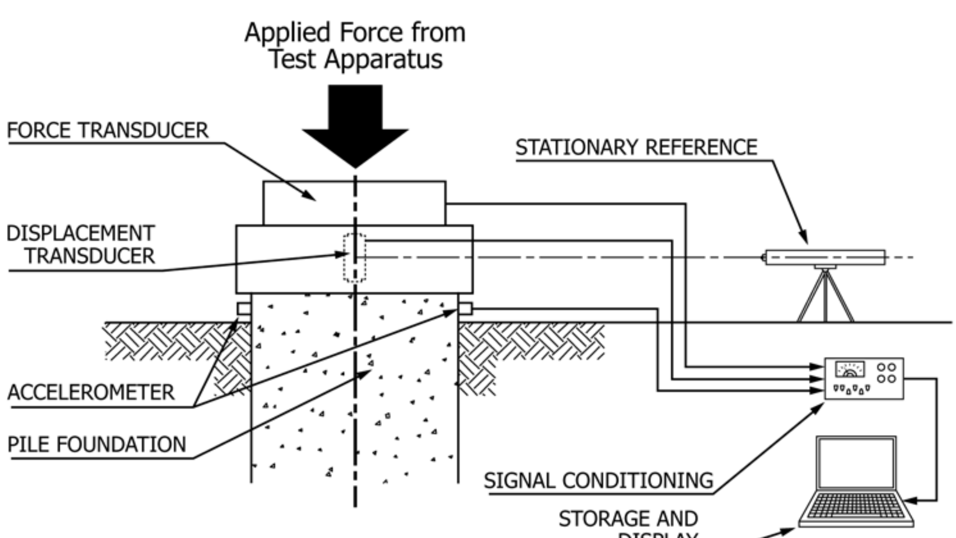

FIG. 4 Apparatus for Conditioning, Recording and Displaying Signals from an Axial Compressive Force Pulse

5.4.3 A secondary apparatus for measuring axial pile head displacement is required, and shall consist of accelerometers, redundant displacement transducers, or other apparatus as approved by the Engineer. Accelerometers indicate pile head displacement by doubly integrating the acceleration signal. Securely attach a minimum of two calibrated acceleration transducers at symmetrical locations with respect to and parallel to the central longitudinal pile axis (see Fig. 4), or one calibrated transducer at and parallel to the central longitudinal pile axis. The resonant frequency of the accelerometers shall be greater than 5 kHz, and the accelerometers shall be linear to at least 50 g. The transducers shall be calibrated to an accuracy of 3 % throughout the applicable measurement range. Bolt-on, glue-on, or weld-on accelerometers are acceptable. The accelerometers may also be attached to a force-distribution plate or another part of the testing apparatus that is firmly attached to the pile head.

NOTE 5—Direct displacement measurements generally provide better accuracy than that obtained by double integration of acceleration.

NOTE 6—In situations where physical restrictions prevent the use of a stationary reference, the Engineer may approve acceleration transducers as the primary displacement measurement system, with appropriate redundancy in the measurements, notation in the report, and independent verification of final set (see Section 6).

5.4.4 Optional or supplemental transducers may consist of bolt-on, weld-on, glue-on, or embedded force or strain transducers, or additional accelerometers or displacement transducers. Specifications for these transducers shall be consistent with those for similar measurements as required in 5.4. The location and specifications of all optional or supplemental transducers shall be approved by the Engineer and described in the test report as per Section 8. When the duration of the force pulse as described in Section 3 is less than the required $12L/c$, supplemental transducers are required along the pile length. These required transducers shall be placed within a distance from either end of the pile, and at incremental distances along the pile, no more than the actual force pulse duration multiplied by $c/12$.

NOTE 7—Supplemental transducers, as described in 5.4.4, may assist in the measurement of the force pulse distribution in the pile during the application of the axial compressive force pulse and is useful for detailed analysis and interpretation.

5.4.5 All components of the apparatus for obtaining measurements shall be calibrated to the standards and recommendations of the manufacturer to meet the requirements of this section. If the pile top force measurement is not within 3 % of the total weight of the reaction or drop mass when it is applied statically to the pile top, then it shall be recalibrated. Unless the applicable project specifications require a more frequent calibration, the calibration interval shall be the lesser of *(a)* two years or *(b)* the manufacturer's recommended calibration interval. Transducers damaged during handling or use shall be repaired as necessary and recalibrated prior to further use.

5.5 *Conditioning, Recording, and Displaying Data:*

5.5.1 *General*—The signals from the transducers (5.4) shall be transmitted to a system to collect and store the raw test data in digital form. The collection and storage system shall be connected to a system to graphically or numerically display the results. The data acquisition system shall acquire a recorded signal with at least 500 ms of consecutive data, including a minimum of 50 ms of pre-force pulse data.

5.5.2 *Signal Conditioning*—The signal conditioning of any signals shall not create differential phase shift or differential amplification of individual measurements. Frequency components shall have a minimum low pass cut off frequency of 1000 Hz.

5.5.3 *Recording Apparatus*—Signals from transducers shall be recorded digitally. When digitizing, the sample frequency shall be at least 4000 Hz for each data channel.

5.5.4 *Display Apparatus*—Signals from the transducers shall be displayed by means of an apparatus such as a digital graphics screen, or computer monitor. The apparatus shall display all signals with respect to time. The apparatus shall also be capable of displaying the measured force pulse with respect to displacement.

5.5.5 All components of the apparatus for conditioning, recording, and displaying data shall be calibrated to the standards and recommendations of the manufacturer to meet the requirements of this section. Unless the applicable project specifications require a more frequent calibration, the calibration interval shall be the lesser of *(a)* two years, or *(b)* the manufacturer's recommended calibration frequency.

6. Procedure

6.1 *General Preparation—Procedure A and B:*

6.1.1 Where a soil base will be used to support the test apparatus, the area shall be leveled and compacted as required. Where a fabricated platform is used, the structure must be able to support all loads associated with the operation of the test apparatus including assembly, execution of the test, and disassembly.

6.1.2 Allow sufficient time for driven and cast-in-place deep foundations constructed of concrete to gain adequate structural strength prior to testing. Prepare the pile head for testing by removing any deleterious or unsound materials to provide a flat, competent contact surface perpendicular to the longitudinal axis of the test pile. Modify the pile head, weld a pile cap to the pile head, place a pile cap on a thin layer of non-shrink cementitious grout at the pile head, place a pile cushion on the pile head, or use a combination of these methods so that the applied force pulse is evenly distributed to the full test pile cross-section, or to a large enough percentage of the cross-sectional area such that the force induced by the target peak force does not exceed 75 % of the compressive strength developed at the time of testing (less any prestress) for concrete piles or 80 % of the yield strength for steel or wood piles. For test piles with protruding reinforcing steel, place a steel pile extension (follower) within or around the protruding reinforcing steel, or temporarily extend the pile concrete to an elevation above the reinforcing steel.

6.1.3 The pile head elevation shall be surveyed and recorded. The horizontal location (position) of the pile may also be surveyed and recorded.

NOTE 8—Deep foundations sometimes include hidden defects that may go unnoticed prior to force pulse testing and adversely affect the test results. Low strain integrity tests as described in Test Method D5882 and ultrasonic crosshole integrity tests as described in Test Method D6760 may provide a useful pre-test evaluation of the test foundation.

6.1.4 Any part of the test apparatus requiring attachment to the pile shall be attached in a manner that is capable of withstanding the forces and accelerations induced during assembly, execution of the test, and disassembly.

6.1.5 The apparatus for measuring the displacement, acceleration, or both, and any optional transducers, shall be attached to or positioned on the pile in accordance with the requirements of 5.4. Supplemental transducers as described in 5.4 are typically installed on or in the pile during pile construction, but if applicable, should be installed at this point in the test procedure. The apparatus for measuring the applied force pulse shall be centered on the test pile cross-section.

6.1.6 All electronic connections shall be cleaned and inspected. Checks of grounding and shielding shall be made prior to testing.

6.1.7 All electrical cables used for the monitoring of the force, displacement, and acceleration transducers shall be connected to the test apparatus and to the apparatus for conditioning, recording and displaying the data.

6.1.8 The resistance of the force transducer shall be checked to ensure it is within the specifications provided.

6.1.9 A check of the displacement monitoring system shall be made for adequate set up, stability, focus, and direction, or other as required by the manufacturer. The aim and alignment of the stationary reference shall be established so that the full range of the displacement transducer (5.4.2) can be utilized.

6.1.10 A check of the storage computer memory shall be made to ensure sufficient storage space is available to acquire and store the test data.

6.1.11 A check shall be performed on the data acquisition software and hardware, including a trigger and calibration check using a simulated test signal of known magnitude.

6.1.12 To ensure a stable stationary reference for displacement monitoring, ground vibrations in the test area must be minimized. This may require a suspension of construction activities in the area during the test.

6.2 *Procedure A—Combustion Gas Pressure Apparatus:*

6.2.1 Prior to testing, the test apparatus shall be cleaned and greased, any seals should be checked and replaced as required.

6.2.2 The safety pressure release mechanism (5.2.9) shall be inspected to ensure that it is in place, properly installed, and not obstructed or damaged.

6.2.3 The plenum shall be inspected to ensure that it is free of obstructions, perforations or dents and the plenum vent shall be checked for any damage or lodged material that may become air-born with normal pressure release.

6.2.4 The piston shall be centered on the test pile cross-section and parallel to the longitudinal axis of the pile.

6.2.5 The means or mechanism for arresting the reaction mass shall be centered with respect to the piston and supported on the ground surrounding the pile, or on a work platform surrounding the pile.

6.2.6 The amount of combustible substance or fuel chosen to reach the target peak force shall be installed in the piston, and the ignition mechanism shall be checked for proper resistance and electrical continuity. Any ignition safety mechanisms shall be tested at this time.

6.2.7 Freedom of movement of the piston and cylinder of the test apparatus shall be demonstrated prior to continuing the assembly.

6.2.8 A force transducer reading shall be recorded prior to placement of the cylinder portion of the test apparatus; a reading from the primary displacement transducer shall also be recorded.

6.2.9 The cylinder portion of the test apparatus shall be placed on the piston and another reading from the force transducer shall be recorded.

6.2.10 The reaction masses shall be placed on the cylinder reaction flange and readings from the force transducer shall be taken periodically to verify proper function of the conditioning, recording and displaying system; a reading from the primary force and displacement transducers shall also be taken upon completion of the reaction mass assembly. The final reading from the force transducer will serve as the 'pre-load' value shown in Fig. 1. Discrepancies between the measured force transducer reading and the known weight of the masses should be investigated and the assembly procedure should be halted until the discrepancies are resolved.

6.2.11 Assembly of the mechanism for catching the reaction mass shall be completed.

6.2.12 A final verification shall be made ensuring that all safety requirements have been followed in accordance with Section 7.

6.3 *Procedure B—Cushioned Drop Mass Apparatus:*

6.3.1 The guide frame for the drop mass shall be centered on the test pile cross-section, and parallel to the longitudinal axis of the pile. The guide frame shall be supported by the ground surrounding the pile or by a work platform surrounding the pile.

6.3.2 Additional support for the guide frame such as blocking or outriggers shall be positioned and the location and alignment of the guide frame shall be checked and adjusted as necessary.

6.3.3 Hydraulic connections for the raising, catching (if applicable), and releasing of the drop mass shall be inspected for leaks and tested for proper function.

6.3.4 Initial readings from the force transducer and the primary displacement transducer shall be recorded.

6.3.5 The drop mass shall be raised to the pre-determined height chosen to reach the target peak force; this drop-height shall be measured and recorded.

6.3.6 A final verification shall be made ensuring that all safety requirements have been followed in accordance with Section 7.

6.4 *Force Pulse Application Procedure:*

6.4.1 Firmly attach to the test pile any external force or displacement instrumentation not installed prior to placing the load apparatus.

6.4.2 Prepare the conditioning and recording system to acquire data.

6.4.3 Initiate the axial compressive force pulse, ensuring that all safety requirements have been met in accordance with Section 7. Use the apparatus described in 5.5 during the force pulse to record and display the signals from the transducers described in 5.4. Following the force pulse, secure the test apparatus for safe entry into the test area by test personnel.

6.4.4 After applying the force pulse, record readings of the residual force and displacement, if applicable.

6.4.5 A final survey of the pile head elevation shall be performed. Use this elevation to calculate the net displacement from the initial survey elevation (see 6.1.3) for comparison with the displacement measurements obtained during the test.

6.4.6 Inspect the measured force pulse to determine if it meets the definition of Section 3 and reaches the target peak force. If the applied force pulse does not have the required characteristics as defined in Section 3, then adjust the apparatus and repeat the test. If the purpose of the test is to estimate the ultimate axial static compression capacity, the Engineer should determine if the net permanent displacement of the test pile is adequate for such purpose (see Section 4).

6.4.7 A test report shall be prepared in accordance with Section 8.

NOTE 9—Hidden defects in the test pile may go unnoticed during a force pulse test. Low strain integrity tests as described in Test Method D5882 and ultrasonic crosshole integrity tests as described in Test Method D6760 may provide a useful post-test evaluation for test piles that are to be used in a permanent foundation.

7. Safety Requirements

7.1 All operations in connection with the testing of the pile shall be carried out in such a manner as to minimize, avoid, or eliminate the exposure of the workplace and personnel to hazards. The following safety considerations are to be followed in addition to the general safety requirements applicable to all construction activities. All applicable construction codes and regulations still apply. If the force pulse is generated by gas pressure from the combustion of materials that are classified as explosives or pyrotechnics, the appropriate authorities shall be notified, the required permits obtained, and the appropriate safety precautions taken.

7.1.1 The test apparatus shall be carefully aligned and the mounting system shall be secured concentrically and axially to ensure that it is not dislodged during the test, and to ensure against eccentric loading or damage to the pile.

7.1.2 The ground surrounding the test pile shall be adequately prepared, leveled, or compacted to support any test-produced loads and to prevent damage to the pile, the test apparatus, or surrounding material.

7.1.3 The routine used to initiate the force pulse application shall ensure against premature initiation until such time as all recommended checks are completed and personnel are clear of the test area, defined as a radius of 20 m from the test pile for Procedure A, and a radius of 5 m from the test pile for Procedure B. A key-operated initiation device is recommended.

7.1.4 Any mechanisms, seals, lubrication, or preparations shall be checked for condition and replaced as necessary to prevent unsafe conditions before, during, or after the test event.

7.1.5 If compressed gas is used in the production of the force pulse an adequate system for the safe venting or dispensing of the gas must be provided. Control of any venting noises must be made to accommodate governing noise limitations.

7.1.6 Loads shall not be hoisted, moved, or suspended over personnel and shall be controlled by ropes or otherwise.

7.1.7 Only authorized personnel shall be permitted within the test area.

8. Report

8.1 The report of an axial compressive force pulse test shall include any information required by the Engineer plus the following information when applicable and as available:

8.2 *General:*

8.2.1 Project identification and location, and

8.2.2 Log(s) of nearby or typical test boring(s).

8.3 *Pile Installation Equipment :*

8.3.1 *For Driven Piles*—Description of driving methods and installation equipment, for example, make, model, and type of hammer, size (ram weight and stroke), manufacturer's energy rating, capabilities, operating performance levels or pressures, fuel settings, hammer cushion and pile cushion descriptions with cushion exchange details, leads, and any special installation equipment such as a follower, mandrel, punch, pre-drill or jet.

8.3.2 *For Cast-in-Place Concrete Piles*—Description of construction methods, drilling or augering equipment, and concrete or grout placement, for example, type of drill rig, type and dimensions of drill tool(s), auger(s), and cleanout tool(s), tremie, concrete or grout pump, and casings.

8.4 *Test Pile:*

8.4.1 Identification and location of test pile,

8.4.2 Required ultimate axial static compressive capacity,

8.4.3 Type and dimensions of test pile, including nominal or actual cross-sectional area, or both, length, wall thickness of pipe or casing, and diameter (as a function of length for tapered or composite deep foundations),

8.4.4 For timber piles: straightness, preservative treatment, tip and butt dimensions (and area as a function of length), and measured density for each pile,

8.4.5 For driven or cast-in-place concrete piles: date(s) test pile constructed or cast, design and measured concrete or grout strength and date of test(s), density, effective prestress, and description of internal and external reinforcement (type, grade, size, length, number and arrangement of prestress wire, longitudinal bars, lateral ties, and spiral stiffeners ; casing or shell size and length),

8.4.6 For steel piles: steel designation, grade, yield strength, and type of pile (for example, seamless or spiral weld pipe, H section designation),

8.4.7 Description and location of splices, special pile tip protection, and any special coatings applied if applicable,

8.4.8 Inclination angle from vertical, design and installed, and

8.4.9 Observations of deep foundations including spalled areas, cracks, head surface of deep foundations.

8.5 *Test Pile Installation:*

8.5.1 Date of test pile installation and embedment below reference,

8.5.2 For cast-in-place piles, include the volume of concrete or grout placed in deep foundation (volume versus depth, if available), and a description of special installation procedures used, such as casing installation or extraction, or both,

8.5.3 For driven piles, include driving records with blow count, and hammer stroke or operating level for final unit penetration,

8.5.4 Elevations of the pile top, pile bottom, and ground surface referenced to a datum, and

8.5.5 Cause and duration of installation interruptions and notation of any unusual occurrences during installation or excavation, if applicable and related to the investigation.

8.6 *Compressive Force Pulse Application and Test Results:*

8.6.1 Description, calibration data and last date of calibration of all components of the apparatus for obtaining measurements and apparatus for conditioning, recording, and displaying data,

8.6.2 Location of displacement and acceleration transducers,

8.6.3 Location and distance of stationary reference,

8.6.4 Testing date,

8.6.5 Description of special instrumentation such as strain rods or gages, accelerometers, or other, including their location with respect to the test pile, and their detailed technical specifications and calibrations,

8.6.6 Graphical representation of force versus time, including an indication of any pre-load on the pile due to the weight of the test apparatus or reaction mass, or both (if applicable),

8.6.7 Graphical representation of displacement versus time using a common time scale with 8.6.6,

8.6.8 Measured force versus displacement plot including a representation of the theoretical elastic stiffness of the pile (for reference only),

8.6.9 Graphical representation of velocity versus time using a common time scale with 8.6.6,

8.6.10 Graphical representation of acceleration versus time using a common time scale with 8.6.6,

8.6.11 Graphical representation of data collected from any optional instrumentation,

8.6.12 A numerical presentation of the applied force, displacement, velocity, and acceleration versus time in milliseconds, reporting time at the precision of the digitizing rate and the former quantities, plus any intermediate quantities used in their calculation, with three significant digits, but not to exceed the precision of their measurement,

8.6.13 Notation of any unusual occurrences during testing,

8.6.14 Results of pile integrity checks performed as part of test procedure,

8.6.15 Groundwater level during test,

8.6.16 Temperature and weather conditions during tests,

8.6.17 Net residual displacement for each force pulse application event with comparison to the minimum displacement required for ultimate axial capacity prediction, reporting displacement with three significant digits, but not to exceed the precision of the measurement, and

8.6.18 Summary and description of the analysis method used including assumptions, limitations, and applied reduction factors, if appropriate.

9. Precision and Bias

9.1 *Precision*—Test data on precision is not presented due to the nature of these test methods. 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 these test methods that might be used to make a limited statement on precision.

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

10. Keywords

10.1 axial compressive force pulse; displacement response; inertial reaction mass; rapid load test; ultimate axial pile capacity