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Standard Test Methods for Deep Foundation Elements Under Static Axial Tensile Load[1]

This standard is issued under the fixed designation D3689/D3689M; 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 measure the axial deflection of an individual vertical or inclined deep foundation element or group of elements when loaded in static axial tension. These methods apply to all types of deep foundations, or deep foundation systems, as they are practical to test. The individual components of which are referred to herein as elements that function as, or in a manner similar to, drilled shafts; cast-in-place piles (augered cast-in-place piles, barrettes, and slurry walls); driven piles, such as pre-cast concrete piles, timber piles or steel sections (steel pipes or wide flange beams); or any number of other element types, regardless of their method of installation. Although the test methods may be used for testing single elements or element groups, the test results may not represent the long-term performance of the entire deep foundation system. A summary of the test methods is contained in Section 4.

1.2 This standard provides minimum requirements for testing deep foundation elements under static axial tensile load. Project plans, specifications, provisions, or any combination thereof may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program. The engineer in charge of the foundation design, referred to herein as the foundation engineer, shall approve any deviations, deletions, or additions to the requirements of this standard. (Exception: the test load applies to the testing apparatus shall not exceed the rated capacity established by the engineer who designed the testing apparatus.)

1.3 Apparatus and procedures herein designated "optional" may produce different test results and may be used only when approved by the foundation engineer. The word "shall" indicates a mandatory provision, and the word "should" indicates a recommended or advisory provision. Imperative sentences indicate mandatory provisions.

1.4 The foundation engineer should interpret the test results obtained from the procedures of this standard to predict the actual performance and adequacy of elements used in the constructed foundation.

1.5 An engineer qualified to perform such work shall design and approve all loading apparatus, loaded members, and support frames. The foundation engineer shall design or specify the test procedures. 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 requirements of the standard. This standard also includes illustrations and appendices intended only for explanatory or advisory use.

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 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound [lbf] represents a unit of force [weight], while the unit for mass is slug. The rationalized slug unit is not given, unless dynamic [F=ma] calculations are involved.

1.8 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. The procedure used to specify how data are collected, recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering data.

1.9 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 design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.10 *This standard offers an organized collection of information or a series of options and does not recommend a*

[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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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 in 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 means only that the document has been approved through the ASTM consensus process.

1.11 *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.*

1.12 *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.*

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
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
D7949 Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations
D8169/D8169M Test Methods for Deep Foundations Under Bi-Directional Static Axial Compressive Load

2.2 *ASME Standards:*[3]

ASME B30.1 Jacks
ASME B40.100 Pressure Gages and Gauge Attachments
ASME B89.1.10.M Dial Indicators (For Linear Measurements)

3. Terminology

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

3.2.2 *deep foundation element, n*—a relatively slender structural element that transmits some or all of the load it supports to soil or rock well below the ground surface, such as a steel pipe or concrete-filled drilled shaft.

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

3.2.4 *failure load, n*—the test load at which continuing, progressive movement occurs, or at which the total axial movement exceeds the value specified by the foundation engineer.

3.2.5 *gage or gauge, n*—an instrument used for measuring load, pressure, displacement, strain or such other physical properties associated with load testing as may be required.

3.2.6 *reaction, n*—a device or deep foundation element or elements designed to provide resistance in the opposite direction of the test load.

3.2.7 *telltale rod, n*—an unstrained metal rod extended through the test element from a specific point to be used as a reference from which to measure the change in the length of the loaded element.

3.2.8 *toe, n*—the bottom of a deep foundation element, sometimes referred to as tip or base.

3.2.9 *wireline, n*—a steel wire mounted with a constant tension force between two supports and used as a reference line to read a scale indicating movement of the test element.

4. Summary of Test Method

4.1 This standard provides minimum requirements for testing deep foundation elements under static axial tensile load. The test is a specific type of test, most commonly referred to as deep foundation load testing or static load testing. This standard is confined to test methods for loading a deep foundation element or elements from the top, in the upward direction. The loading requires devices or structural elements be constructed that resist downward movement, often referred to collectively as a reaction system. The principal measurements taken in addition to load are displacements.

4.2 This standard allows the following test procedures:

Method A	Quick Test	10.1.2
Method B	Maintained Test	10.1.3
Method C	Constant Rate of Uplift Test	10.1.4

5. Significance and Use

5.1 Field tests provide the most reliable relationship between the axial load applied to a deep foundation and the resulting axial movement. Test results may also provide information used to assess the distribution of side shear resistance along the element and the long-term load-deflection behavior. The foundation engineer may evaluate the test results to determine if, after applying appropriate factors of safety, the element or group of elements has a static capacity, load response and deflection at service load satisfactory to support the foundation. When performed as part of a multiple-element test program, the foundation engineer may also use the results

[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] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

to assess the viability of different sizes and types of foundation elements and the variability of the test site.

5.2 If feasible and without exceeding the safe structural load on the element or element cap (hereinafter unless otherwise indicated, "element" and "element group" are interchangeable as appropriate), the maximum load applied should reach a failure load from which the foundation engineer may determine the axial static tensile load capacity of the element. Tests that achieve a failure load may help the foundation engineer improve the efficiency of the foundation design by reducing the foundation element length, quantity, and/or size.

5.3 If deemed impractical to apply axial test loads to an inclined element, the foundation engineer may elect to use axial test results from a nearby vertical element to evaluate the axial capacity of the inclined element. The foundation engineer may also elect to use a bi-directional axial test on an inclined element (D8169/D8169M).

5.4 Different loading test procedures may result in different load-displacement curves. The Quick Test (10.1.2) and Constant Rate of Uplift Test (10.1.4) typically can be completed in a few hours. Both are simple in concept, loading the element relatively quickly as load is increased. The Maintained Test (10.1.3) loads the element in larger increments and for longer intervals, which could cause the test duration to be significantly longer. Because of the larger load increments the determination of the failure load can be less precise, but the Maintained Test is thought to give more information on creep displacement. Although control of the Constant Rate of Uplift Test is somewhat more complicated (and uncommon for large diameter or capacity elements), the test may produce the best possible definition of capacity. The foundation engineer must weigh the complexity of the procedure and other limitations against any perceived benefit.

5.5 The scope of this standard does not include analysis for foundation capacity in tension, but in order to analyze the test data appropriately it is important that information on factors that affect the derived mobilized static axial tensile capacity are properly documented. These factors may include, but are not limited to, the following:

5.5.1 Potential residual loads in the element which could influence the interpreted distribution of load along the element shaft.

5.5.2 Possible interaction of friction loads from test element with downward friction transferred to the soil from reaction elements obtaining part or all of their support in soil at levels above the tip level of the test element.

5.5.3 Changes in pore water pressure in the soil caused by element driving, construction fill, and other construction operations which may influence the test results for frictional support in relatively impervious soils such as clay and silt.

5.5.4 Differences between conditions at time of testing and after final construction such as changes in grade or groundwater level.

5.5.5 Potential loss of soil supporting the test element from such activities as excavation and scour.

5.5.6 Possible differences in the performance of an element in a group or of an element group from that of a single isolated element.

5.5.7 Effect on long-term element performance of factors such as creep, environmental effects on element material, negative friction loads not previously accounted for, and strength losses.

5.5.8 Type of structure to be supported, including sensitivity of structure to settlements and relation between live and dead loads.

5.5.9 Special testing procedures which may be required for the application of certain acceptance criteria or methods of interpretation.

5.5.10 Requirement that non-tested element(s) have essentially identical conditions to those for tested element(s) including, but not limited to, subsurface conditions, element type, length, size and stiffness, and element installation methods and equipment, so that application or extrapolation of the test results to such other elements is valid. For concrete elements, it is sometimes necessary to use higher amounts of reinforcement in the test elements in order to safely conduct the test to the predetermined required test load. In such cases, the foundation engineer shall account for the difference in stiffness between the test elements and non-tested elements.

5.5.11 Tension tests are sometimes used to validate element compression capacity in addition to tension capacity. When subjected to tension loads, elements may have different stiffness and structural capacity compared to elements subjected to compression loads.

NOTE 1—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/sampling/inspection/etc. 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.

6. Test Foundation Preparation

6.1 Excavate or add fill to the ground surface around the test element to the final design elevation unless otherwise approved by the foundation engineer. Type of fill and compaction requirements shall be as specified by the foundation engineer.

6.2 Design and construct the test element so that any location along the depth of the element will safely sustain the maximum anticipated loads to be developed at that location. Cut off or build up the test element as necessary to permit construction of the load-application apparatus, placement of the necessary testing and instrumentation equipment, and observation of the instrumentation. Remove any damaged or unsound material from the element top as necessary to properly install the apparatus for measuring movement, for applying load, and for measuring load.

6.3 For tests on element groups, cap the element group with steel-reinforced concrete or a steel load frame designed for the anticipated loads by the structural engineer.

6.4 Install structural tension connectors extending from the test element or element cap, constructed of steel straps, bars, cables, and/or other devices bolted, welded, cast into, or