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

This standard is issued under the fixed designation D3966/D3966M; 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 lateral deflection of an individual vertical or inclined deep foundation element or group of elements when subjected to static lateral loading. These methods apply to all 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, micropiles, 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 H-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.

1.2 This standard provides minimum requirements for testing deep foundation elements under static lateral 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 applied 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 as 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.

1.8.1 The procedures 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 specific course of action. This document cannot replace education or experience and should be used in conjunction with*

[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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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]

A36/A36M Specification for Carbon Structural Steel
A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A572/A572M Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1143/D1143M Test Methods for Deep Foundation Elements Under Static Axial Compressive Load
D3689/D3689M 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 and Data Records in Geotechnical Data
D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing
D6230 Practices for Monitoring Earth or Structural Movement Using Inclinometers
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 *American Society of Mechanical Engineer Standards:*[3]

ASME B30.1 Jacks
ASME B40.100 Pressure Gauges and Gauge Attachments
ASME B46.1 Surface Texture
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 element, n*—a deep foundation unit made of cement grout or concrete and constructed in its final location, for example, drilled shafts, bored elements, caissons, auger cast elements, pressure-injected footings, etc.

3.2.2 *deep foundation, 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 pile or concrete drilled shaft.

3.2.3 *driven element, n*—a deep foundation unit 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 lateral movement exceeds the value specified by the foundation engineer.

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

3.2.6 *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.

4. Summary of Test Method

4.1 This standard provides minimum requirements for testing deep foundation elements under lateral load. The test is a specific type of test, most commonly referred to as a lateral load test. This standard is confined to test methods for loading deep foundation elements from the side. The loading requires constructing a reaction system that resists the applied lateral load. One or more deep foundation elements can be used as reaction. The principal measurements taken in addition to load are displacements.

4.2 This standard allows the following test procedures:

Procedure	Test	Section
A	Standard Loading	10.1.2
B	Excess Loading	10.1.3
C	Cyclic Loading	10.1.4
D	Surge Loading	10.1.5
E	Reverse Loading	10.1.6
F	Reciprocal Loading	10.1.7
G	Specified Lateral Movement	10.1.8
H	Combined Loading	10.1.9

5. Significance and Use

5.1 Field tests provide the most reliable relationship between the static lateral load applied to a deep foundation and the resulting lateral movement. Test results may also provide information used to assess the distribution of lateral resistance along the element and the long-term load-deflection behavior. The foundation engineer may evaluate the test results to

[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, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

determine if, after applying the appropriate factors, the element or group of elements has an ultimate lateral capacity and a deflection at service load satisfactory to satisfy specific foundation requirements. When performed as part of a multiple-element test program, the foundation engineer may also use the results to assess the viability of different sizes and types of foundation elements and the variability of the test site.

5.2 The analysis of lateral test results obtained using proper instrumentation helps the foundation engineer characterize the variation of element-soil interaction properties, such as the coefficient of horizontal subgrade reaction, to estimate bending stresses and lateral deflection over the length of the element for use in the structural design of the element.

5.3 If feasible, 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 lateral load capacity of the element. Tests that achieve a failure load may help the designer improve the efficiency of the foundation by reducing the foundation element-length, quantity, or size.

5.4 If deemed impractical to apply lateral test loads to an inclined element, the foundation engineer may elect to use lateral test results from a nearby vertical element to evaluate the lateral capacity of the inclined element.

5.5 The scope of this standard does not include analysis for foundation lateral capacity, but in order to analyze the test data appropriately it is important that information on factors that affect the lateral load-deformation behavior are properly documented. These factors may include, but are not limited to the following:

5.5.1 Subgrade condition and preparation near ground surface.

5.5.2 Height at which lateral load is applied above ground surface.

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 deflections 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 the non-tested elements.

6. Test Foundation Preparation

6.1 Excavate or add fill to the test area to the final grade elevation within a radius of 6 m [20 ft] from the test element or group using the same material and backfilling methods as for production elements. Cut off or build up the test element(s) 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.

6.2 For tests of single elements, install solid steel test plate(s) at least 50 mm [2 in.] thick against the side of the element at the point(s) of load application and perpendicular to the line of the load action. The test plate shall have side dimensions not more than, and not less than one half of, the diameter or side dimension of the test element(s). The test plate(s) shall span across and between any unbraced flanges on the test element.

6.3 For tests on element groups, cap the element group with steel-reinforced concrete or a steel load frame designed and constructed to safely sustain and equally distribute the anticipated loads. The connection between the elements and the cap shall simulate in-service conditions. Element caps shall be cast above grade unless otherwise specified and may be formed on the ground surface.

6.4 For each loading point on a element cap, provide a solid steel test plate oriented perpendicular to the axis of the element group with a minimum thickness of 50 mm [2 in.], as needed to safely apply load to the element cap. Center a single test plate on the centroid of the element group. Locate multiple test plates symmetrically about the centroid of the element group.

6.5 To minimize stress concentrations due to minor irregularities of the element surface, set test plates bearing on precast or cast-in-place concrete elements in a thin layer of quick-setting, non-shrink grout, less than 6 mm [0.25 in.] thick and having a compressive strength greater than the test element at the time of the test. Set test plates designed to bear on a concrete element cap in a thin layer of quick-setting, non-shrink grout, less than 6 mm [0.25 in.] thick and having a compressive strength greater than the element cap at the time of the test. For tests on steel elements, or a steel load frame,