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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, weld the test plates to the element or load frame. For test elements without a flat side of adequate width to mount the test plate, cap the head of the element to provide a bearing surface for the test plate or set the test plate in high-strength grout. In all cases, provide full bearing for the test plate against the projected area of the element.

6.6 *Elimination of Element Cap Friction (Optional)*—Provide a clear space beneath the element cap as specified by the foundation engineer. This option isolates the lateral response of the elements from that of the element cap.

6.7 *Passive Soil Pressure Against Element Cap (Optional)*—Develop passive soil pressure against the element cap by constructing the element cap below the ground surface and backfilling with compacted fill on the side opposite the point of load application, or by constructing the element cap above the ground surface against an embankment. If specified, place compacted against the sides of the element cap to the extent practicable.

NOTE 1—Deep foundations sometimes include hidden defects that may go unnoticed prior to static testing. Low strain integrity tests as described in Test Method D5882, ultrasonic crosshole integrity tests as described in Test Method D6760, and/or thermal integrity profiling as described in Test Methods D7949 may provide a useful pre-test evaluation of the test foundation. While the former two methods can be done at any time, including after the test, thermal integrity profiling must be done relatively soon after the concrete element is cast.

NOTE 2—When testing a cast-in-place concrete element such as a drilled shaft, the size, shape, material composition and properties of the element can influence the element capacity and the interpretation of strain measurements described in Section 9, if used.

7. Safety Requirements

7.1 All operations in connection with element load testing shall be carried out in such a manner to minimize, avoid, or eliminate the exposure of people to hazard. The following safety rules are in addition to general safety requirements applicable to construction operations:

7.1.1 Keep all test and adjacent work areas, walkways, platforms, etc. clear of scrap, debris, small tools, and accumulations of snow, ice, mud, grease, oil, or other slippery substances.

7.1.2 Provide timbers, blocking, and cribbing materials made of quality material and in good serviceable condition with flat surfaces and without rounded edges.

7.1.3 Hydraulic jacks shall be equipped with hemispherical bearing plates or shall be in complete and firm contact with the bearing surfaces and shall be aligned to avoid eccentric loading.

7.1.4 Loads shall not be hoisted, swung, or suspended over anyone and shall be controlled by tag lines.

7.1.5 The test apparatus shall be designed and approved by a qualified engineer and installed to transmit the required loads with an adequate factor of safety.

7.1.6 All jacks, bearing plates, test beam(s), or frame members shall be firmly fixed into place or adequately blocked to prevent slippage under load and upon release of load.

7.1.7 All reaction components shall be stable and balanced. During testing, monitor movements of the reaction system to detect impending unstable conditions.

7.1.8 All test members, reaction frames, and test apparatus shall be adequately supported at all times.

7.1.9 Only authorized personnel shall be permitted within the immediate test area, and only as necessary to monitor test equipment. The overall load test plan should include all provisions and systems necessary to minimize or eliminate the need for personnel within the immediate test area. All reasonable effort shall be made to locate pumps, load cell readouts, data loggers, and test monitoring equipment at a safe distance away from jacks, loaded beams, weighted boxes, dead weights, and their supports and connections.

8. Apparatus for Applying and Measuring Loads

8.1 *General:*

8.1.1 The apparatus for applying lateral loads to a test element or element group shall conform to one of the methods described in 8.3 – 8.7. Unless otherwise specified, construct the test apparatus so that the resultant loads are applied horizontally, at approximately element cut-off elevation, and in line with the central vertical axis of the element or element group to minimize eccentric loading and avoid a vertical load component. The apparatus for applying and measuring loads described in this section shall be designed in accordance with recognized standards by a qualified engineer who shall clearly define the maximum allowable load that can be safely applied.

NOTE 3—For lateral tests on inclined element frames or element groups involving inclined elements, consider applying the lateral test loads at the actual or theoretical point of intersection of the longitudinal axis of the elements in the frame or group.

8.1.2 *Struts and Blocking*—Struts shall be of steel and of sufficient size and stiffness to transmit the applied test loads without bending or buckling. Blocking used between reaction elements or between the hydraulic jack and the reaction system shall be of sufficient size and strength to prevent crushing or other distortion under the applied test loads.

8.1.3 Reaction elements, if used, shall be of sufficient number and installed to safely provide adequate reaction capacity without excessive movement. When using two or more reaction elements at each end of the test beam(s), cap or block them as needed to develop the reaction load. Locate reaction elements so that resultant test beam load supported by them acts at the center of the reaction element group. Cribbing or deadmen, if used as a reaction, shall be of sufficient plan dimensions and weight to transfer the reaction loads to the soil without excessive lateral movement that would prevent maintaining the applied loads.

8.1.4 Provide a clear distance between the test element(s) and the reaction elements or cribbing of at least five times the maximum diameter of the largest test or reaction element(s), but not less than 2.5 m [8 ft]. The foundation engineer may increase or decrease this minimum clear distance based on factors such as the type and depth of reaction, soil conditions, and magnitude of loads so that reaction forces do not significantly affect the test results.

NOTE 4—Excessive vibrations during reaction element installation in non-cohesive soils may affect test results. Reaction elements that penetrate deeper than the test element may affect test results. Install the anchor elements nearest the test element first to help reduce installation effects.

8.1.5 Each jack shall include a lubricated hemispherical bearing or similar device to minimize lateral loading of the element or element group. The hemispherical bearing(s) should include a locking mechanism for safe handling and setup.

8.1.6 Provide bearing stiffeners as needed between the flanges of test and reaction beams.

8.1.7 Provide steel bearing plates to spread the load to and between the jack(s), load cell(s), hemispherical bearing(s), test beam(s), reaction beam(s), and reaction element(s). Unless otherwise specified by the engineer, the size of the bearing plates shall be not less than the outer perimeter of the jack(s), load cell(s), or hemispherical bearing(s), nor less than the total width of the test beam(s), reaction beam(s), reaction elements to provide full bearing and distribution of the load. Bearing plates supporting the jack(s), test beam(s), or reaction beams on timber or concrete cribbing shall have an area adequate for safe bearing on the cribbing.

8.1.8 Unless otherwise specified, where using steel bearing plates, provide a total plate thickness adequate to spread the bearing load between the outer perimeters of loaded surfaces at a maximum angle of 45 degrees to the loaded axis. For center hole jacks and center hole load cells, also provide steel plates adequate to spread the load from their inner diameter to their central axis at a maximum angle of 45 degrees, or per manufacturer recommendations.

8.1.9 Align all struts, blocking, bearing plates, jacks, load cells, hemispherical bearings, and testing apparatus to minimize eccentric loading, and, where necessary, restrain them from shifting as test loads are applied so as not to affect the test results and to prevent instability. Test members and apparatus shall have flat, parallel bearing surfaces. Design and construct the support reactions to prevent instability and to limit undesired rotations or lateral displacements.

8.1.10 Unless otherwise specified by the engineer, design and construct the apparatus for applying and measuring loads, including all struts and structural members, of steel with sufficient size, strength, and stiffness to safely prevent excessive deflection and instability up to 125 % of the maximum anticipated test load.

8.1.11 Inspect all tension rods, lines, rope, cable, and their connections used for pull tests to insure good, serviceable condition. Unless otherwise specified by the engineer, design and construct these tension members with sufficient strength to safely resist a load at least 50 % greater than the maximum anticipated test load. Tension members with a cross-sectional area reduced by corrosion or damage, or with material properties compromised by fatigue, bending, or excessive heat, may rupture suddenly under load. Do not use brittle materials for tension connections.

8.1.12 A qualified engineer shall design and approve all aspects of the loading apparatus, including loaded members, support frames, connections, reaction elements, instruments and loading procedures. The apparatus for applying and measuring loads (except for hydraulic jacks and load cells), including all structural members, shall have sufficient size, strength, and stiffness to safely prevent excessive deflection and instability up to the maximum anticipated test load.

8.2 *Hydraulic Jacks, Gauges, Transducers, and Load Cells:*

8.2.1 The hydraulic jack(s) and their operation shall conform to ASME B30.1 and shall have a nominal load capacity exceeding the maximum anticipated jack load by at least 20 %. The jack, pump, and any hoses, pipes, fittings, gauges, or transducers used to pressurize it shall be rated to a safe pressure corresponding to the nominal jack capacity.

8.2.2 The hydraulic jack ram(s) shall have a travel greater than the sum of the anticipated maximum axial movement of the element plus the deflection of the reaction system and the elongation of the tension connection, but not less than 15 % of the average element diameter or width. Use a single high capacity jack when possible. When using a multiple jack system, provide jacks of the same make, model, and capacity, and supply the jack pressure through a common manifold with a master pressure gauge. Fit the manifold and each jack with a pressure gauge to detect malfunctions and imbalances.

8.2.3 Unless otherwise specified, the hydraulic jack(s), pressure gauge(s), and pressure transducer(s) shall have a calibration to at least the maximum anticipated jack load, over their complete range of piston travel for increasing and decreasing applied loads and performed within the six months prior to each test or series of tests. Hydraulic jacks used in double-action shall be calibrated in both the push and pull modes. Furnish the calibration report(s) prior to performing a test, which shall include the ambient temperature and calibrations performed for multiple ram strokes up to the maximum stroke of the jack.

8.2.4 If the lateral load is applied by pulling, the apparatus used to produce the pulling force shall be capable of applying a steady constant force over the required load testing range. The dynamometer(s), or other in-line load indicating device(s), shall be calibrated to an accuracy within 10 % of the applied load.

8.2.5 Each complete jacking and pressure measurement system, including the hydraulic pump, should be calibrated as a unit when practicable. The hydraulic jack(s) shall be calibrated over the complete range of ram travel for increasing and decreasing applied loads. If two or more jacks are to be used to apply the test load, they shall be of the same make, model, and size, connected to a common manifold and pressure gauge, and operated by a single hydraulic pump. The calibrated jacking system(s) shall have accuracy within 5 % of the maximum applied load. When not feasible to calibrate a jacking system as a unit, calibrate the jack, pressure gauges, and pressure transducers separately, and each of these components shall have accuracy within 2 % of the applied load.

8.2.6 Pressure gauges and pressure transducers shall have minimum graduations less than or equal to 1 % of the maximum applied load and shall conform to ASME B40.100 with an accuracy grade 1A having a permissible error ±1 % of the span. When used for control of the test, pressure transducers shall include a real-time display.

8.2.7 If the maximum test load will exceed 900 kN [100 tons], place a properly positioned load cell or equivalent device in series with each hydraulic jack or pulling apparatus. Unless otherwise specified the load cell(s) shall have a calibration to at least the maximum anticipated jack load performed within the six months prior to each test or series of tests. The calibrated load cell(s) or equivalent device(s) shall have accuracy within 1 % of the applied load, including an eccentric loading of up to 1 % applied at an eccentric distance of 25 mm [1 in.]. After calibration, load cells shall not be subjected to impact loads. A load cell is recommended, but not required, for lesser load. If not practicable to use a load cell when required, include embedded strain gauges located in close proximity to the jack to confirm the applied load.

8.2.8 Do not leave the hydraulic jack pump unattended at any time during the test. An automatic regulator is recommended to help hold the load constant as element movement occurs. Automated jacking systems shall include a clearly marked mechanical override to safely reduce hydraulic pressure in an emergency.

8.3 *Load Applied by Hydraulic Jack(s) Acting Against a Reaction System (Fig. 1):*

8.3.1 *General*—Apply the test loads to the element or element group using one or more hydraulic cylinders and a suitable reaction system according to 8.3.2, 8.3.3, 8.3.4, or 8.3.5. The reaction system may be any convenient distance from the test element or element group and shall provide a resistance greater than the anticipated maximum lateral test load. Set the hydraulic cylinder(s) (with load cell(s) if used) against the test plate(s) at the point(s) of load application in a horizontal position and on the line(s) of load application. Place a steel strut(s) or suitable blocking between the base(s) of the cylinder(s) and the reaction system with steel bearing plates between the strut(s) or blocking and the cylinder(s) and

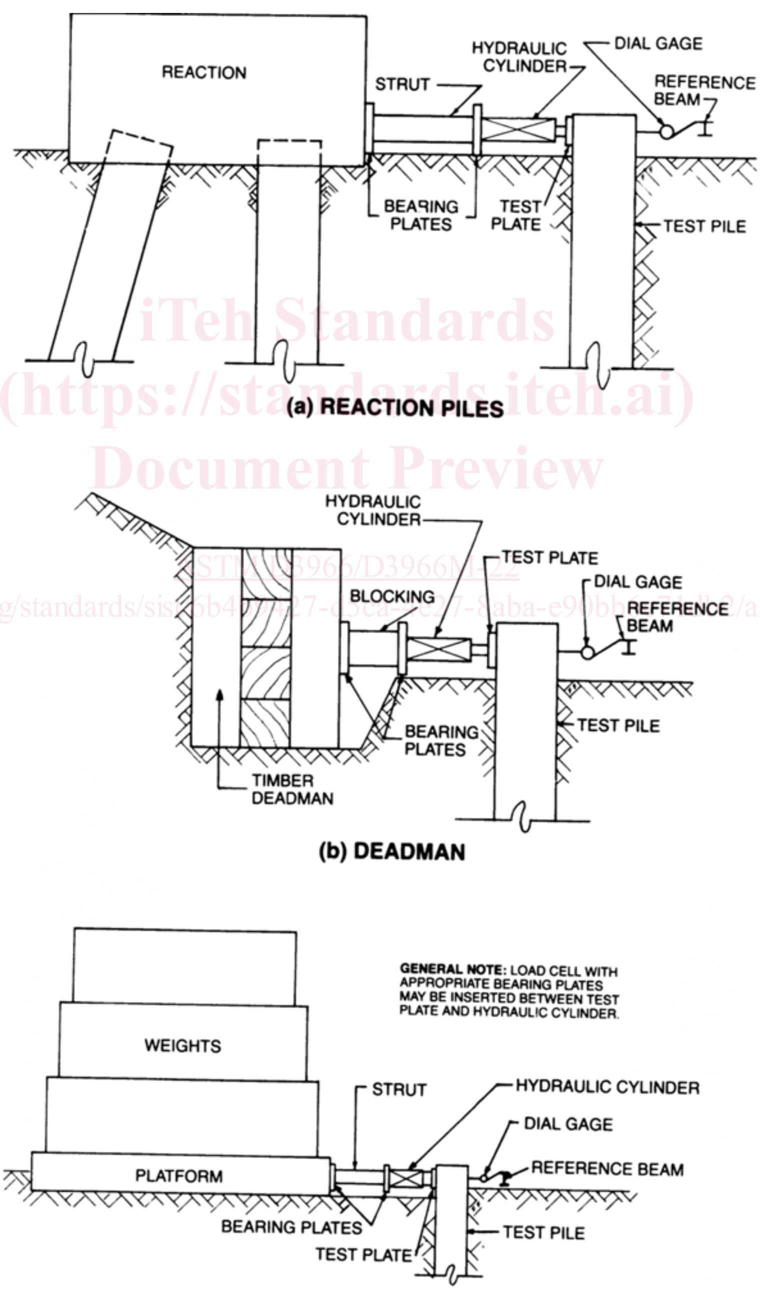

FIG. 1 Typical Set-ups for Applying Lateral Load with Conventional Hydraulic Jack

between the strut(s) and the reaction system. If a steel strut(s) is used, place it horizontally and on the line(s) of load application and brace the strut(s) to ensure it does not shift during load application. If two hydraulic jacks are used, place the jacks, load cells (if used), and struts or blocking at the same level and equidistant from a line parallel to the lines of load application and passing through the center of the test group. Support the jack(s), bearing plate(s), strut(s), and blocking on cribbing if necessary for stability.

8.3.2 *Reaction Elements (*Fig. 1*a)*—Install two or more reaction elements vertically or on an incline (or a combination of vertical and incline) to provide the necessary reactive capacity for the maximum anticipated lateral test loads. Cap the reaction elements with reinforced concrete, steel, or timber, or brace between the elements, or fasten the tops of the elements together to develop the lateral resistance of the entire group. Install any inclined reaction elements in a direction away from the test element or group (see Fig. 1*a*).

8.3.3 *Deadman (*Fig. 1*b)*—Where soil or site conditions are suitable, install a deadman consisting of cribbing, timber panels, sheeting, or similar construction bearing against an embankment or the sides of an excavation to provide the necessary reactive capacity to the maximum anticipated lateral test loads.

8.3.4 *Weighted Platforms (*Fig. 1*c)*—Construct a platform of any suitable material such as timber, concrete, or steel, and load the platform with sufficient weights to provide the necessary resistance to the maximum anticipated lateral test loads to be applied. Provide a suitable bearing surface on the edge of the platform against which the reactive lateral load will be applied.

8.3.5 *Other Reaction Systems (Optional)*—Use any other specified suitable reaction system such as an existing structure.

8.4 *Load Applied by Hydraulic Jack(s) Acting Between Two Test Elements or Test Element Groups (*Fig. 2*)*—Test the lateral capacity of two single elements or two similar element groups simultaneously by applying either a compressive or tensile force between the element or element groups with a hydraulic jack(s). Test elements or test groups may be any convenient distance apart. If necessary, insert a steel strut(s) between the hydraulic jack(s) and one of the test elements or groups. Remove all temporary blocking and cribbing underneath plates, strut(s), and cylinder(s) (and load cell(s) if used), after the first load increment has been applied and do not brace any strut(s).

8.5 *Load Applied by Pulling (Optional):*

8.5.1 *General*—Apply the lateral load by pulling test element or group using a suitable power source such as a hydraulic jack, turnbuckle or winch connected to the test element or group with a suitable tension member such as a wire rope or a steel rod and connected to an adequate reaction system or anchorage. Securely fasten the tension member to the test element or element cap so that the line of load application passes through the vertical central axis of the test element or group. If two tension members are used, fasten them to the test element or element cap at points equidistant from a line parallel to the lines of load application and passing through the vertical central axis of the test element or group.

8.5.2 *Anchorage System*—Maintain a clear distance of not less than 6 m [20 ft] or 20 element diameters between the test element or group and the reaction or anchorage system complying with 8.3, or as otherwise specified by the foundation engineer. Furnish an anchorage system sufficient to resist without significant movement the reaction to the maximum lateral load to be applied to the test element or group.

8.5.3 *Pulling Load Applied by Hydraulic Jack Acting against a Reaction System (*Fig. 3*)*—Apply the lateral tensile load to the test element or element group using any suitable hydraulic cylinder such as conventional type, push-pull type, or center-hole type. Center the conventional hydraulic cylinder (and load cell if used) on the line of load application with its base bearing against a suitable reaction system and its piston acting against a suitable yoke attached by means of two parallel tension members to the test element or element group (see Fig. 3*a*). Where required to adequately transmit the jacking load, install steel bearing plates. If a double-acting hydraulic jack is used (Fig. 3*b*), place the jack cylinder on the line of load application connecting the cylinder's casing to the anchorage system and the jack piston to a suitable strut or steel rod adequately secured to the test element or element group. The steel strut or rod may be supported at intermediate points provided such supports do not restrain the strut or rod from moving in the direction of load application. If a center-hole jack is used (Fig. 3*c*), center the jack cylinder (and load cell if used) along the line of load application with its base bearing against a suitable reaction and with its piston acting against a suitable clamp or nut attached to a steel rod or cable fastened securely to the test element or group. Provide a hole through the reaction system for the tension member. If necessary to transmit the jacking forces, insert a steel bearing plate between the reaction and the jack base.

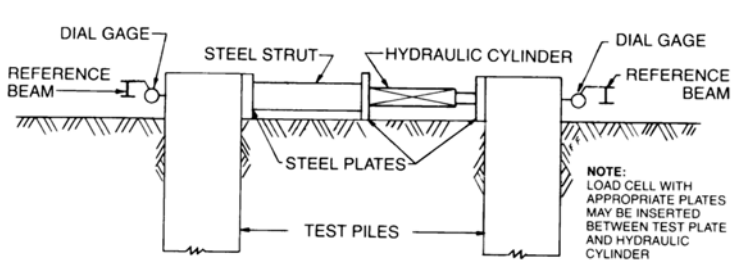

FIG. 2 Typical Arrangement for Testing Two Elements Simultaneously