



Designation: D 3966 – 90 (Reapproved 1995)

Standard Test Method for Piles Under Lateral Loads¹

This standard is issued under the fixed designation D 3966; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures for testing vertical and batter piles either individually or in groups to determine the load-deflection relationship when subjected to lateral loading. It is applicable to all deep foundation units regardless of their size or method of installation. This test method is divided into the following sections:

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1.2 This test method only describes procedures for testing single piles or pile groups. It does not cover the interpretation or analysis of the test results or the application of the test results to foundation design or the use of empirical or analytic procedures for determining the magnitude and variation of the coefficient of horizontal subgrade reaction, bending stresses, and bending movements over the length of the pile. The term “failure” as used in this test method indicates a rapid progressive lateral movement of the pile or pile group under a constant or decreasing load.

1.3 Apparatus and procedures designated “optional” are to be required only when included in the project specifications and, if not specified, may be used only with the approval of the engineer responsible for the foundation design. The word “shall” indicates a mandatory provision and “should” indicates a recommended or advisory provision. Imperative sentences indicate mandatory provisions. Notes and illustrations included herein are explanatory or advisory.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 *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 appro-*

priate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific safety precautions, see Section 8.

2. Referenced Documents

2.1 ASTM Standards:

A 36/A 36M Specification for Structural Steel²

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels²

A 441/A 441M Specification for High-Strength Low-Alloy Structural Manganese Vanadium Steel²

A 572/A 572M Specification for High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality²

D 1143 Test Method for Piles Under Static Axial Compressive Load³

D 3689 Test Method for Individual Piles Under Static Axial Tensile Load³

2.2 ANSI Standards:⁴

B30.1 Safety Code for Jacks

B46.1 Surface Texture

3. Significance and Use

3.1 The actual lateral load capacity of the pile-soil system can best be determined by lateral testing. Such testing measures the response of the pile-soil system to lateral loads and may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

3.2 Under the iterative elastic method of analysis that considers the nonlinear response of the soil,⁵ lateral testing combined with proper instrumentation can be used to determine soil properties necessary for the structural design of the pile to resist the lateral load to be applied.

3.3 Lateral testing as covered herein, when combined with an acceptance criterion, is suitable for control of pile foundation design and installation under building codes, standards, and other regulatory statutes.

¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.11 on Deep Foundations.

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² Annual Book of ASTM Standards, Vol 01.04.

³ Annual Book of ASTM Standards, Vol 04.08.

⁴ Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

⁵ Reece, L. C., “Design and Evaluation of Load Tests on Deep Foundations,” *Behavior of Deep Foundations*, ASTM STP 670, Am. Soc. Testing Mats., 1979.

4. Apparatus for Applying Loads

4.1 General:

4.1.1 The apparatus for applying lateral loads to the test pile(s) shall be as described in 4.3 or 4.4, unless otherwise specified, and shall be constructed so that the resultant loads are applied horizontally and in line with the central vertical axis of the pile or pile group so as to minimize eccentric loading and avoid a vertical load component.

NOTE 1—For lateral tests on batter pile frames or pile groups involving batter piles, consideration should be given to applying the lateral test loads at the actual or theoretical point of intersection of the longitudinal axis of the piles in the frame or group.

4.1.2 The test area within a radius of 20 ft (6 m) from the test pile or group shall be excavated or filled to the final grade elevation before testing the pile or pile group. If necessary, the pile(s) shall be cut off or extended so that the pile butt(s) is sufficiently above adjacent ground surface to permit construction of the load application apparatus, placement of the necessary testing and instrumentation equipment, and observation of the instrumentation. Before applying the test load, any annular space around the upper portion of the test pile(s) should be filled with sand or other suitable material and the same material and backfilling methods should be used for all production piles. Lateral test loads shall be applied at approximately pile cut-off elevation.

4.1.3 For tests on pile groups, except batter pile frames, the group of piles shall be capped with a reinforced concrete cap designed and constructed in accordance with accepted engineering practice to distribute the test loads uniformly to the piles in the group or shall be interconnected with steel members designed and constructed so that the piles act together. The connection between piles and pile caps and the depth of embedment of the pile butts into the pile cap shall simulate in-service conditions. Pile caps shall be cast above grade unless otherwise specified and may be formed on the ground surface unless 4.1.3.1 is specified.

4.1.3.1 *Elimination of Friction Beneath Pile Cap* (Optional)—For tests on pile groups, the bottom of the pile cap shall be clear of the ground surface.

NOTE 2—It is recommended that the bottom of the pile cap be clear of the ground surface when the friction between the soil and the pile cap may contribute significantly to the lateral resistance of the pile group.

4.1.3.2 *Passive Soil Pressures Against Pile Cap* (Optional)—For tests on pile groups, the pile cap shall be constructed below ground surface and backfilled with compacted fill on the side opposite the point of load application or the pile cap shall be constructed above ground surface against an embankment sufficient to permit the passive soil pressures to act during the test. If specified, compacted fill shall be placed against the sides of the pile cap to the extent practicable.

4.1.4 A steel test plate(s) of sufficient stiffness to prevent it from bending under the involved loads, but not less than 2 in. (50 mm) thick, shall be set vertically against the side of the pile, pile cap, or steel frame at the point(s) of load application and perpendicular to the line(s) of load application. The test plate shall be of sufficient size to accommodate the hydraulic cylinders but shall have a horizontal side dimension not less

than one half the diameter or side dimension of the test pile(s) nor greater than the diameter or side dimension of the test pile(s). For tests on single piles other than square piles, the head of the pile shall be capped so as to provide a plane vertical bearing surface for the test plate, or the test plate shall be set in high-strength grout or adequately welded to the side of the pile using suitable filler material to provide full bearing against the projected area of the pile. If the test plate(s) is supported independently of the test pile or group during assembly of the testing apparatus, such temporary supports shall be removed when test loads are applied.

4.1.5 *Bearing Plates*, shall be of steel and of sufficient size to accommodate spherical bearings, load cells, hydraulic jacks, and struts, and to transmit the applied lateral loads without detrimental high unit pressures. Bearing plates shall be of adequate thickness to prevent bending under the applied load but shall not be less than 2 in. (50 mm) thick.

4.1.6 *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 piles or between the hydraulic cylinder and the reaction system shall be of sufficient size and strength to prevent crushing or other distortion under the applied test loads.

4.2 Testing Equipment:

4.2.1 Unless the test load is applied by pulling in accordance with 4.5, lateral loads shall be applied using one or more hydraulic cylinders equipped with spherical bearings. If two or more hydraulic cylinders are to be used to apply the test load, they shall be of the same piston diameter, connected to a common manifold and pressure gage, and operated by a single hydraulic pump.

4.2.2 Hydraulic jacks including their operation shall conform to the applicable provisions of ANSI B30.1.

4.2.3 Unless a calibrated load cell(s) or equivalent device(s) is used, the complete jacking system including the hydraulic cylinder(s), valves, hydraulic pump, and pressure gage shall be calibrated as a unit to an accuracy of not less than 5 % of the applied load.

4.2.4 When an accuracy greater than that obtainable with the jacking system is required, a properly constructed load cell(s) or equivalent device(s) shall be used in series with the hydraulic cylinder(s). Load cells or equivalent devices shall be calibrated to an accuracy of not less than 2 % of the applied load and shall be equipped with spherical bearings.

4.2.5 If the lateral load is applied by pulling 4.5.4) the equipment used to produce the pulling force shall be capable of applying steady constant forces over the required load testing range. The dynamometer(s) or other in-line load indicating device(s) shall be calibrated to an accuracy of not less than 10 % of the applied load.

4.2.6 Calibration of testing equipment shall be done before each test or series of tests in a test program. Hydraulic cylinders shall be calibrated by loading the test equipment with the hydraulic cylinders over their complete range of piston travel for increasing and decreasing applied loads. Double-acting hydraulic cylinders shall be calibrated in both the push and pull modes. Calibration reports shall be furnished for

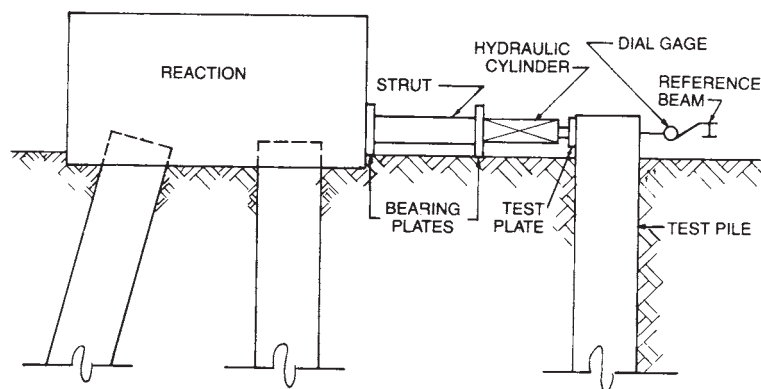
testing equipment for which calibration is required and shall show the temperature at which the calibration was done.

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

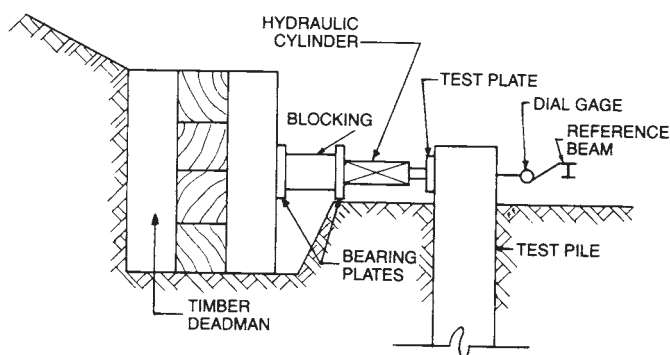
4.3.1 General—Apply the test loads to the pile or pile group using one or more hydraulic cylinders and a suitable reaction system according to 4.3.2, 4.3.3, 4.3.4, or 4.3.5. The reaction system may be any convenient distance from the test pile or pile group and shall provide a resistance greater than 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 in accordance with 4.1.5 between the strut(s) or blocking and the cylinder(s) and 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 cylinders are used, place both cylinders, 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.

4.3.2 Reaction Piles (Fig. 1a)—Install two or more reaction piles vertically or on a batter (or a combination of vertical and batter) so as to provide the necessary reactive capacity for the



(a) REACTION PILES



(b) DEADMAN

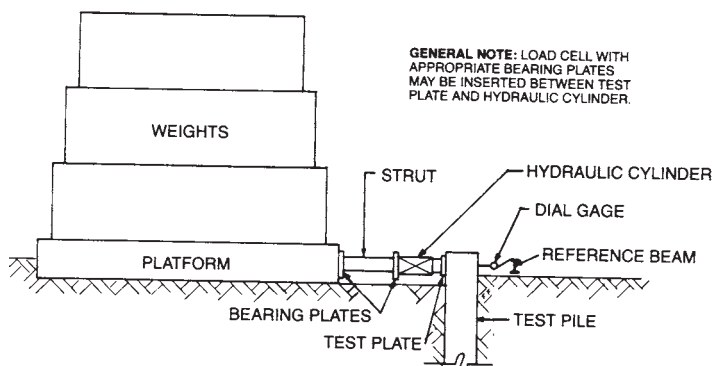


FIG. 1 Typical Set Ups for Applying Lateral Load with Conventional Hydraulic Jack

maximum anticipated lateral test loads. Cap the reaction piles with reinforced concrete, steel, or timber, or brace between the piles, or fasten the pile butts together so as to develop the lateral resistance of the entire group.

NOTE 3—Unless two opposing batter reaction piles are installed, the batter piles should be battered in a direction away from the test pile or group (see Fig. 1a).

4.3.3 Deadman (Fig. 1b)—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 so as to provide the necessary reactive capacity to the maximum anticipated lateral test loads.

4.3.4 Weighted Platforms (Fig. 1c)—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.

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

4.4 Load Applied by Hydraulic Jack(s) Acting Between Two Test Piles or Test Pile Groups (Fig. 2)—Test the lateral capacity of two single piles or two similar pile groups simultaneously by applying either a compressive or tensile force between the pile or pile groups with a hydraulic jack(s). Test piles or test groups may be any convenient distance apart. If necessary, insert a steel strut(s) between the hydraulic cylinder(s) and one of the test piles or groups. For the cylinder(s), load cell(s) (if used), strut(s), and bearing plate(s) (if used), comply with the requirements of 4.1.5, 4.1.6, and 4.3.1, except 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 the strut(s).

4.5 Load Applied by Pulling (Optional):

4.5.1 General—Apply the lateral load by pulling test pile or group using a suitable power source such as a hydraulic jack, turnbuckle or winch connected to the test pile 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 pile or pile cap so that the line of load application passes through the vertical central axis of the test pile or group. If two tension members are used, fasten them to the test pile or pile cap at points

equidistant from a line parallel to the lines of load application and passing through the vertical central axis of the test pile or group.

4.5.2 Anchorage System—Maintain a clear distance of not less than 20 ft (6 m) or 20 pile diameters between the test pile or group and the reaction or anchorage system complying with 4.3.2, 4.3.3, 4.3.4, 4.3.5, or as otherwise specified. Furnish an anchorage system sufficient to resist without significant movement the reaction to the maximum lateral load to be applied to the test pile or group.

4.5.3 Pulling Load Applied By Hydraulic Jack Acting Against a Reaction System (Fig. 3)—Apply the lateral tensile load to the test pile or pile 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 pile or pile group (see Fig. 3a). Where required to adequately transmit the jacking load, install steel bearing plates in accordance with 4.1.5. If a double-acting type cylinder is used (Fig. 3b), place the cylinder on the line of load application connecting the cylinder's casing to the anchorage system and its piston to a suitable strut or steel rod adequately secured to the test pile or pile 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 cylinder is used (Fig. 3c), center the 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 pile 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 in accordance with 4.1.5 between the reaction and the jack base.

4.5.4 Pulling Load Applied By Other Power Source Acting Against An Anchorage System (Fig. 4)—Apply the lateral tensile load with a winch or other suitable device. Insert a dynamometer or other load indicating device in the pulling line between the power source and the test pile or group (see Fig. 4a). If a multiple part line is used, insert the dynamometer or equivalent device in the line connecting the pulling blocks with either the test pile (or group) or the anchorage system. (See Fig. 4b).

4.6 Fixed-Head Test (Optional):

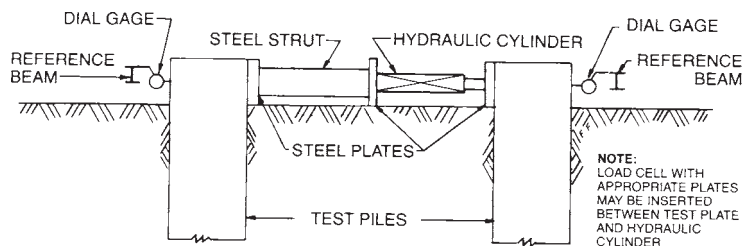
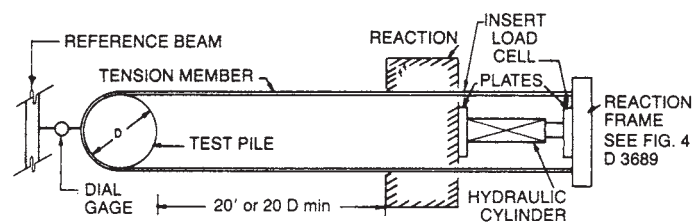
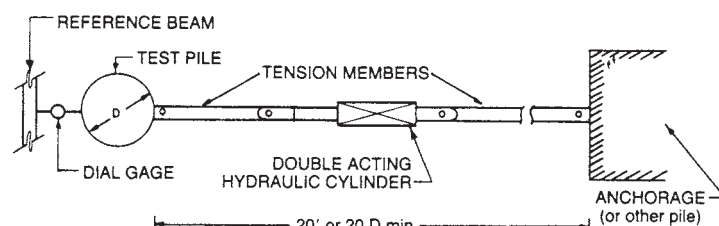


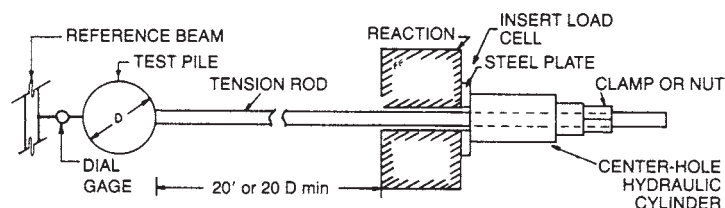
FIG. 2 Typical Arrangement for Testing Two Piles Simultaneously



(a) CONVENTIONAL HYDRAULIC CYLINDER

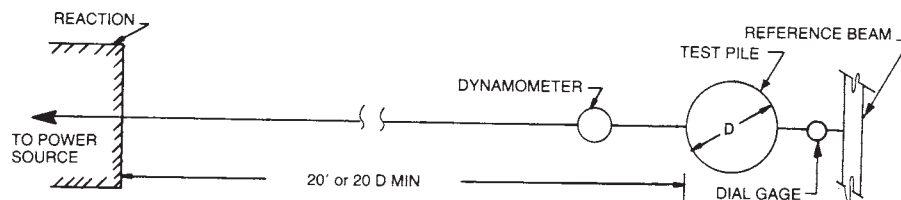


(b) DOUBLE ACTING HYDRAULIC CYLINDER

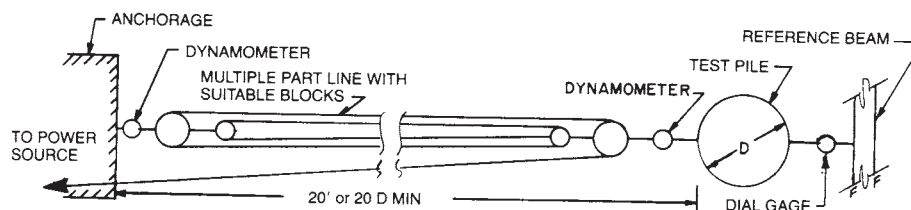


(c) CENTER-HOLE HYDRAULIC CYLINDER

FIG. 3 Typical Arrangements for Applying Pulling Loads with Hydraulic Jack (Top Views)



(a) SINGLE LINE



(b) MULTIPLE PART LINE

FIG. 4 Typical Arrangements for Applying Lateral Loads with Power Source such as Winch (Top Views)

4.6.1 *Individual Pile* (Fig. 5)—Install the test pile so that it extends a sufficient distance above the adjacent ground surface to accommodate the steel frames but not less than 6½ ft (2 m). Firmly attach by clamping, welding, or some other means, a right angle (approximately 30–60–90) frame to each side of

that portion of the pile extending above ground surface. Design and construct the frame so as to prevent the top of the pile from rotating under the maximum lateral load to be applied. Support the ends of the frames on steel rollers acting between steel bearing plates with the bottom bearing plate supported by