



Standard Test Methods for Deep Foundations Under Lateral Load¹

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.

^{ε1} NOTE—Designation was editorially corrected to match units information in June 2013.

1. Scope

1.1 The test methods described in this standard measure the lateral deflection of a vertical or inclined deep foundation when subjected to lateral loading. These methods apply to all deep foundations, referred to herein as “pile(s),” that function in a manner similar to driven piles or cast in place piles, regardless of their method of installation, and may be used for testing single piles or pile groups. The test results may not represent the long-term performance of a deep foundation.

1.2 These test methods provide minimum requirements for testing deep foundations under lateral load. Plans, specifications, provisions, or combinations thereof prepared by a qualified engineer may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program. The engineer in responsible charge of the foundation design, referred to herein as the engineer, shall approve any deviations, deletions, or additions to the requirements of these test methods.

1.3 These test methods allow the following test procedures:

Procedure	Test	Section
A	Standard Loading	8.1.2
B	Excess Loading (Optional)	8.1.3
C	Cyclic Loading (Optional)	8.1.4
D	Surge Loading (Optional)	8.1.5
E	Reverse Loading (Optional)	8.1.6
F	Reciprocal Loading (Optional)	8.1.7
G	Specified Lateral Movement (Optional)	8.1.8
H	Combined Loading (Optional)	8.1.9

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

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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1.5 A qualified geotechnical engineer should interpret the test results obtained from the procedures of these test methods so as to predict the actual performance and adequacy of piles used in the constructed foundation. See Appendix X1 for comments regarding some of the factors influencing the interpretation of test results.

1.6 A qualified engineer shall design and approve all loading apparatus, loaded members, support frames, and test procedures. The text of these test methods 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 test methods. These test methods also include illustrations and appendices intended only for explanatory or advisory use.

1.7 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.

1.8 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 slugs. The rationalized slug unit is not given, unless dynamic [$F=ma$] calculations are involved.

1.9 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.10 The method used to specify how data are collected, calculated, or recorded in these test methods 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.

1.11 ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such

patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.12 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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 Test Method for Piles Under Static Axial Compressive Load (Withdrawn 2005)³
 - D3689 Test Methods for Deep Foundations Under Static Axial Tensile Load
 - D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
 - D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations
 - D6026 Practice for Using Significant Digits in Geotechnical Data
 - D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing
- ### 2.2 American Society of Mechanical Engineer Standards:⁴
- 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 common definitions of terms used in this standard, see Terminology **D653**.

3.2 *Definitions of Terms Specific to This Standard:*

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

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

⁴ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

or rock well below the ground surface, such as a steel pipe pile or concrete drilled shaft.

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

3.2.4 *failure load, n*—for the purpose of terminating a lateral load test, the test load at which continuing, progressive movement occurs, or as specified by the engineer.

3.2.5 *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 pile.

4. Significance and Use

4.1 Field tests provide the most reliable relationship between the 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 pile shaft and the long-term load-deflection behavior. A foundation designer may evaluate the test results to determine if, after applying an appropriate factor of safety, the pile or pile group has an ultimate lateral capacity and a deflection at service load satisfactory to satisfy specific foundation requirements. When performed as part of a multiple-pile test program, the designer may also use the results to assess the viability of different piling types and the variability of the test site.

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

4.3 If feasible, without exceeding the safe structural load on the pile(s) or pile cap, the maximum load applied should reach a failure load from which the engineer may determine the ultimate lateral load capacity of the pile(s). Tests that achieve a failure load may help the designer improve the efficiency of the foundation by reducing the piling length, quantity, or size.

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

NOTE 1—The quality of the result produced by this test method 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 this test method are cautioned that compliance with Practice **D3740** does not in itself assure reliable results. Reliable results depend on many factors; Practice **D3740** provides a means of evaluating some of those factors.

5. Test Foundation Preparation

5.1 Excavate or fill the test area to the final grade elevation within a radius of 6 m [20 ft] from the test pile or group using the same material and backfilling methods as for production piles. Cut off or build up the test pile(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 pile top as necessary to properly install the apparatus for measuring movement, for applying load, and for measuring load.

5.2 For tests of single piles, install solid steel test plate(s) at least 50 mm [2 in.] thick against the side of the pile 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 pile(s). The test plate(s) shall span across and between any unbraced flanges on the test pile.

5.3 For tests on pile groups, cap the pile 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 piles and the cap shall simulate in-service conditions. Pile caps shall be cast above grade unless otherwise specified and may be formed on the ground surface.

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

5.5 To minimize stress concentrations due to minor irregularities of the pile surface, set test plates bearing on precast or cast-in-place concrete piles 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 pile at the time of the test. Set test plates designed to bear on a concrete pile 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 pile cap at the time of the test. For tests on steel piles, or a steel load frame, weld the test plates to the pile or load frame. For test piles without a flat side of adequate width to mount the test plate, cap the head of the pile 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 pile.

5.6 *Elimination of Pile Cap Friction (Optional)*—Provide a clear space beneath the pile cap as specified by the engineer. This option isolates the lateral response of the piles from that of the pile cap.

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

NOTE 2—Deep foundations sometimes include hidden defects that may go unnoticed prior to static testing. Low strain integrity tests as described in Test Method D5882 and ultrasonic crosshole integrity tests as described in Test Method D6760 may provide a useful pre-test evaluation of the test foundation.

6. Apparatus for Applying and Measuring Loads

6.1 General:

6.1.1 The apparatus for applying tensile loads to a test pile or pile group shall conform to one of the methods described in 6.3-6.6. Unless otherwise specified, construct the test apparatus so that the resultant loads are applied horizontally, at approximately pile cut-off elevation, 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 3—For lateral tests on inclined pile frames or pile groups involving inclined piles, consider 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.

6.1.2 *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 piles 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.

6.1.3 Reaction piles, if used, shall be of sufficient number and installed so as to safely provide adequate reaction capacity without excessive movement. When using two or more reaction piles at each end of the test beam(s), cap or block them as needed to develop the reaction load. Locate reaction piles so that resultant test beam load supported by them acts at the center of the reaction pile 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.

6.1.4 Provide a clear distance between the test pile(s) and the reaction piles or cribbing of at least five times the maximum diameter of the largest test or reaction pile(s), but not less than 2.5 m [8 ft]. The 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 effect the test results.

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

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

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

6.1.7 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 pile(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 piles so as 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.

6.1.8 Unless otherwise specified, when 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 the their central axis at a maximum angle of 45 degrees, or per manufacturer recommendations.

6.1.9 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.

6.1.10 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.

6.1.11 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.

6.1.12 A qualified engineer shall design and approve all loading apparatus, loaded members, support frames, and loading procedures.

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

6.2.1 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.

6.2.2 The hydraulic jack ram(s) shall have a travel greater than the sum of the anticipated maximum axial movement of the pile plus the deflection of the test beam and the elongation of the tension connection, but not less than 15 % of the average pile 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.

6.2.3 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.

6.2.4 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.

6.2.5 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.

6.2.6 Pressure gauges 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. Pressure transducers shall have a minimum resolution 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.

6.2.7 If the maximum test load will exceed 900 kN [100 tons], place a properly constructed 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.

6.2.8 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 pile movement occurs. Automated jacking systems shall include a clearly marked mechanical override to safely reduce hydraulic pressure in an emergency.

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

6.3.1 *General*—Apply the test loads to the pile or pile group using one or more hydraulic cylinders and a suitable reaction system according to 6.3.2, 6.3.3, 6.3.4, or 6.3.5. The reaction

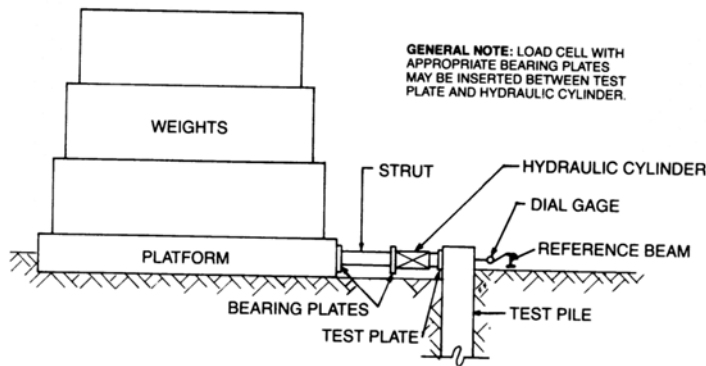
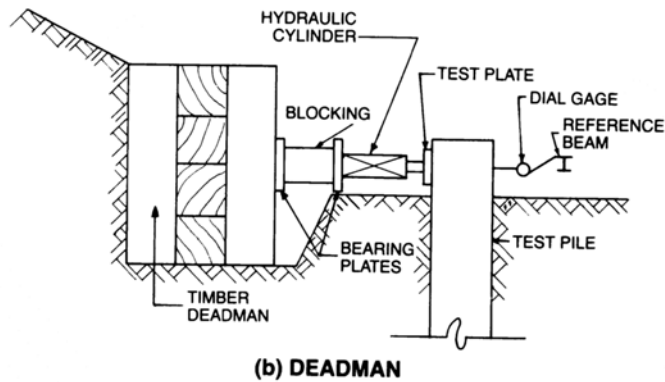
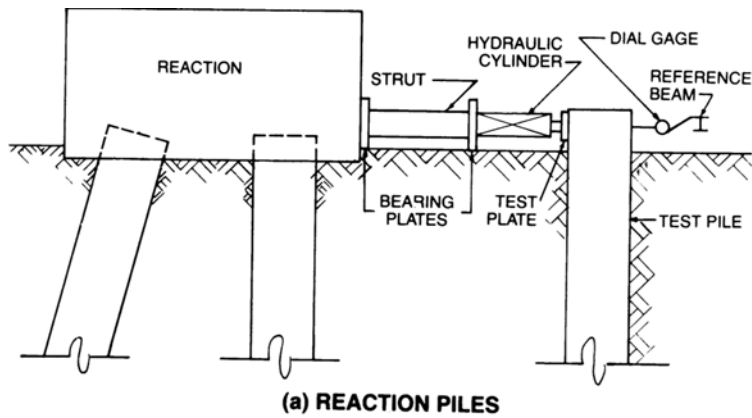


FIG. 1 Typical Set-ups for Applying Lateral Load with Conventional Hydraulic Jack

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 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 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.

6.3.2 *Reaction Piles* (Fig. 1a)—Install two or more reaction piles vertically or on an incline (or a combination of vertical and incline) so as to provide the necessary reactive capacity for the maximum anticipated lateral test loads. Cap the reaction piles with reinforced concrete, steel, or timber, or brace between the piles, or fasten the tops of the piles together so as

to develop the lateral resistance of the entire group. Install any inclined reaction piles in a direction away from the test pile or group (see Fig. 1a).

6.3.3 *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.

6.3.4 *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.

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

6.4 *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 jack(s) and one of the test piles 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).

6.5 *Load Applied by Pulling (Optional):*

6.5.1 *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.

6.5.2 *Anchorage System*—Maintain a clear distance of not less than 6 m [20 ft] or 20 pile diameters between the test pile or group and the reaction or anchorage system complying with 6.3, or as otherwise specified by the engineer. Furnish an anchorage system sufficient to resist without significant move-

ment the reaction to the maximum lateral load to be applied to the test pile or group.

6.5.3 *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. If a double-acting hydraulic jack is used (Fig. 3b), 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 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 jack is used (Fig. 3c), 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 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 between the reaction and the jack base.

6.5.4 *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).

6.6 *Fixed-Head Test (Optional):*

6.6.1 *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 2 m [6.5 ft]. 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 on a

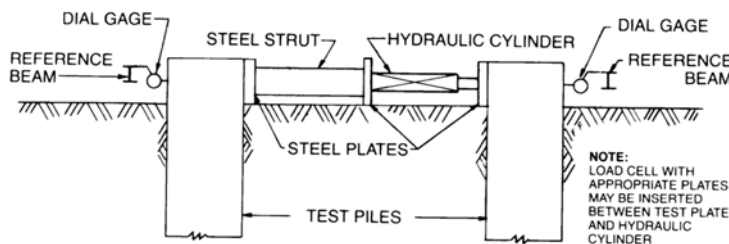
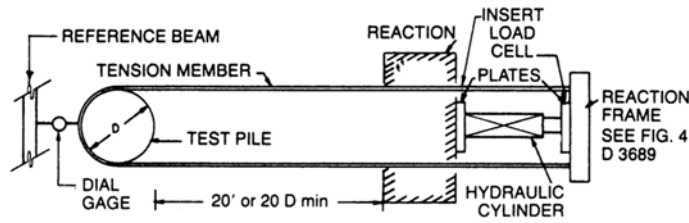
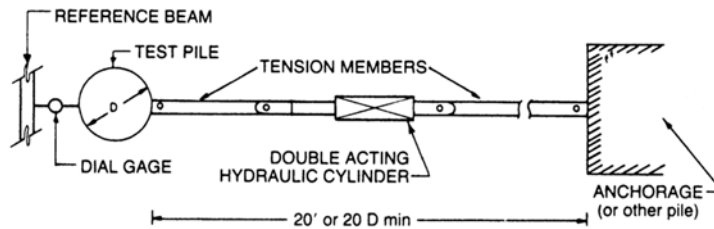


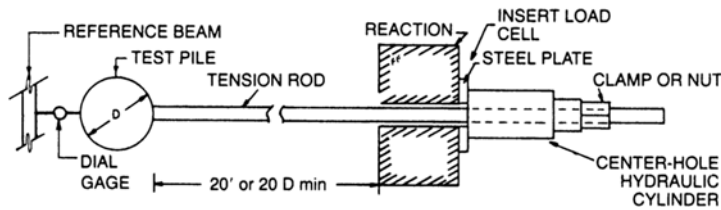
FIG. 2 Typical Arrangement for Testing Two Piles Simultaneously



(a) CONVENTIONAL HYDRAULIC CYLINDER

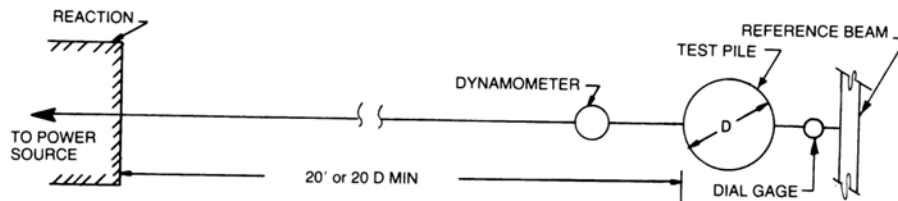


(b) DOUBLE ACTING HYDRAULIC CYLINDER

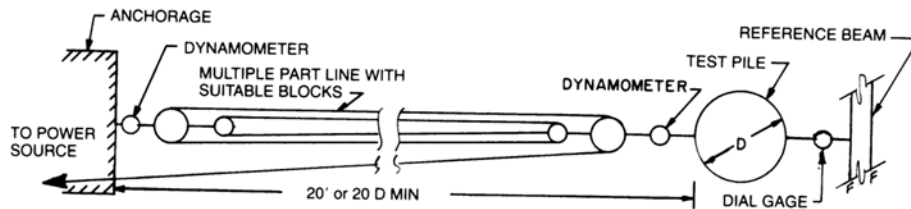


(c) CENTER-HOLE HYDRAULIC CYLINDER

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)

pile(s) or cribbing with sufficient bearing capacity to prevent any significant vertical deflections of the ends of the frame. Maintain a clear distance of not less than 3 m [10 ft] between the test pile and support for the ends of the frames. The steel

bearing plate shall be of sufficient size to accommodate the ends of the frames and the steel rollers including the maximum anticipated lateral travel. Steel rollers shall be solid and shall be of sufficient number and diameter (but not less than 50 mm

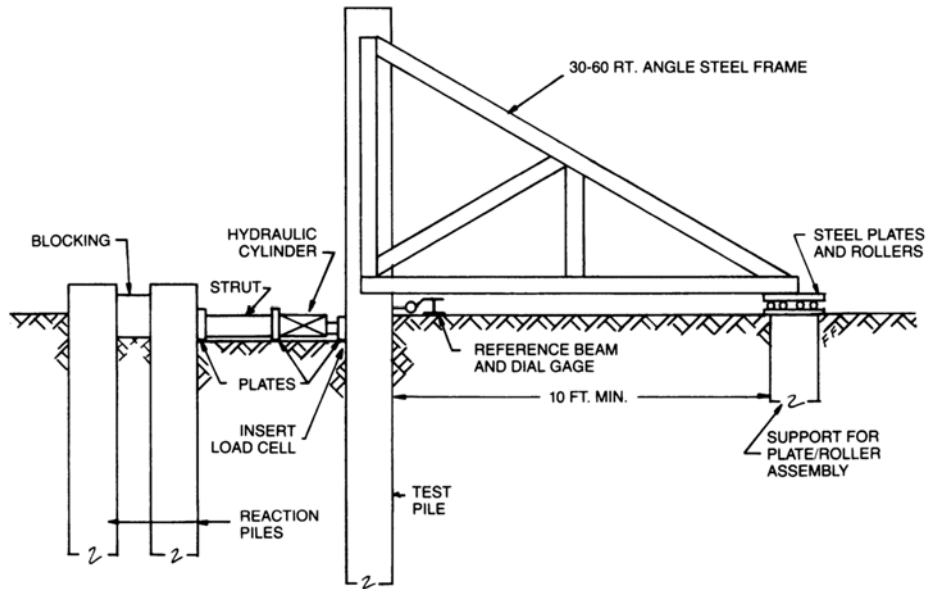


FIG. 5 Example of Fixed-Head Test Set-up for Lateral Test on Individual Pile

[2 in.] in diameter) so as to permit free horizontal movement of the frames under the anticipated downward pressures resulting from the maximum lateral test load to be applied.

NOTE 5—For practical purposes for a 3-m [10-ft] spacing between the test pile and frame support, it can be assumed that the vertical reaction at the ends of the frames is equal to the lateral load being applied to the test pile at the ground surface.

6.6.2 *Pile Group* (Fig. 6)—Install the test piles with pile tops a sufficient distance above the point of load application to provide fixity when the test group is capped. Cap the test group with an adequately designed and constructed reinforced concrete or steel grillage cap with sufficient embedment of the piles in the cap to provide fixity and with the side of the cap opposite the point of load application extended a sufficient distance to provide for the support pile(s). To prevent rotation

of the pile cap under lateral load, support the end of the cap opposite that of the point of load application on one or more bearing piles with steel plates and rollers in accordance with 6.6.1 between the bottom of the cap and the top of the bearing pile(s).

6.7 *Combined Lateral and Axial Loading (Optional):*

6.7.1 *General*—Test the pile or pile group under a combination of lateral loading and axial compressive or tensile loading as specified. Apply the lateral load using method 6.3 or 6.4. Employ suitable methods and construction to ensure that the pile or pile group is not significantly restrained from lateral movement by the axial load.

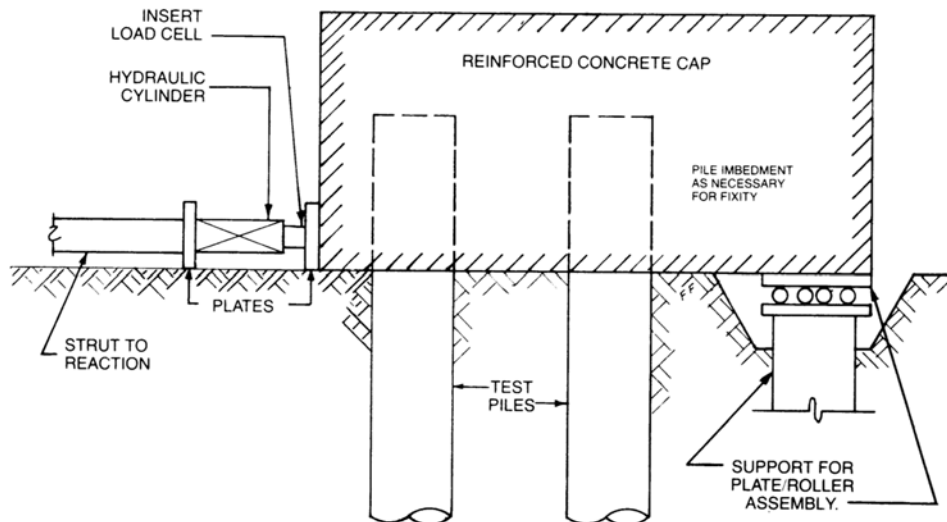


FIG. 6 Example of Fixed-Head Test Set-up for Lateral Test on Pile Group

6.7.2 *Compressive Load* (Fig. 7)—Apply the specified axial compressive load in accordance with Test Method D1143. Place an anti-friction device in accordance with 6.7.2.1, 6.7.2.2, or as otherwise specified between the compressive loading jack and the test plate on top of the test pile or pile group.

6.7.2.1 *Plate and Roller Assembly* (Fig. 8a)—The plate and roller assembly shall be designed to support the maximum applied compressive load without crushing or flattening of rollers and without indentation or distortion of plates, and to provide minimal restraint to the lateral movement of the test pile or group as the lateral test loads are applied. Fig. 8a illustrates a typical assembly having a compressive load limit of 890 kN [100 tons]. The two plates shall be of Specification A572/A572M steel or equal with a minimum yield strength of 290 MPa [42 000 psi] and shall have a minimum thickness of 75 mm [3 in.]. The plates shall have sufficient lateral dimensions to accommodate the length of rollers required for the compressive loads and for the anticipated travel of the rollers as the test pile or group moves laterally under load. The contacting surfaces of the steel plates shall have a minimum surface roughness of 63 as defined and measured by ASME B46.1. The rollers shall be of sufficient number and length to accommodate the compressive loads and shall be of Specification A572/A572M steel Grade 45 or equal (minimum yield strength 310 MPa [45 000 psi]) with a minimum diameter of 75 ± 0.03 mm [3 ± 0.001 in.]. The rollers shall have a minimum surface roughness of 63 as defined and measured by ASME B46.1. The plates shall be set level and the rollers shall be placed perpendicular to the direction of lateral load application with adequate spacing to prevent binding as lateral movement occurs.

6.7.2.2 *Antifriction Plate Assembly* (Fig. 8b)—The antifriction plate assembly shall be designed and constructed as illustrated in Fig. 8b and shall consist of the following elements: (1) a minimum 25-mm (1-in.) thick steel plate, (2) a minimum 3.4 mm (10-gauge) steel plate tack welded to the 25-mm [1-in.] thick plate, (3) a minimum 2.4-mm [$\frac{3}{32}$ -in.] sheet of virgin tetrafluoroethylene polymer with reinforcing aggregates prebonded to the 3.4-mm [10-gauge] plate by a

heat-cured epoxy, and (4) a minimum 6.4-mm [$\frac{1}{4}$ -in.] thick plate of Specification A240/A240M Type 304 stainless steel having a minimum surface roughness of 4 as defined and measured by ASME B46.1. The area of contact between the tetrafluoroethylene polymer and the stainless steel plate shall be sufficient to maintain a unit pressure of less than 14 MPa [2000 psi] under the compressive loads to be applied. The area of the stainless steel plate shall be sufficient to maintain full surface contact with the tetrafluoroethylene polymer as the test pile or group deflects laterally. The stainless steel plate shall be formed with lips on opposite sides to engage the edges of the test plate under the lateral load. During the lateral test, the lips shall be oriented in the direction of the applied lateral load. The use of a plate assembly having an equivalent sliding friction shall be permitted. The use of two steel plates with a layer of grease in between shall not be permitted.

NOTE 6—Combined lateral and axial compressive loading is recommended to simulate in-service conditions. Precautions should be taken to avoid a vertical component resulting from the applied lateral load or a lateral component from the applied axial load.

NOTE 7—An apparatus for applying an axial tensile load to the test pile in combination with a lateral test load is difficult to construct without restraining the test pile from moving laterally under the lateral test loads. If it is required that a pile be tested under combined axial tensile and lateral loading, the use of a suitable crane equipped with a line load indicator is suggested for applying the uplift or tensile loads. Some type of universal acting device should be used in the tension member connecting the test pile with the crane hook. That in combination with the crane falls should minimize restraint against lateral movement of the test pile under lateral loads.

7. Apparatus for Measuring Movement

7.1 General:

7.1.1 Reference beams and wirelines shall be supported independent of the loading system, with supports firmly embedded in the ground at a clear distance from the test pile of at least five times the diameter of the test pile(s) but not less than 2.5 m [8 ft], and at a clear distance from any anchor piles of at least five times the diameter of the anchor pile(s) but not less than 2.5 m [8 ft]. Reference supports shall also be located as far as practicable from any struts or supports but not less than a clear distance of 2.5 m [8 ft].

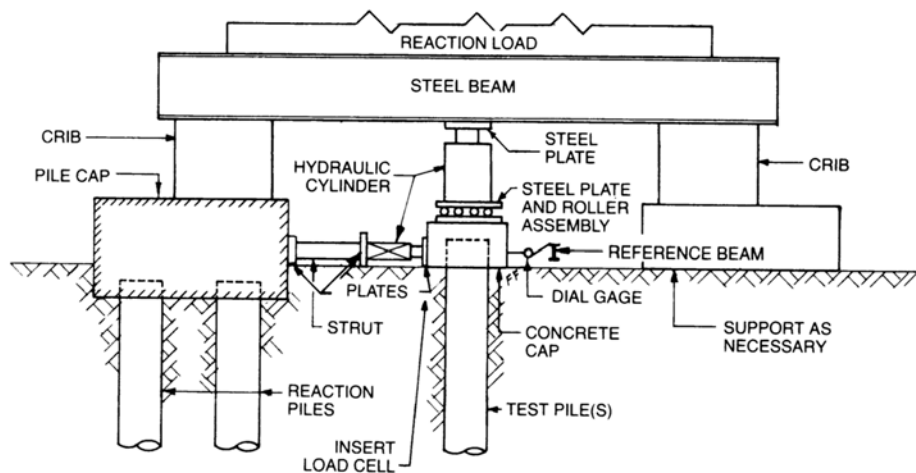


FIG. 7 Typical Example of Set-up For Combined Lateral and Axial Compressive Load

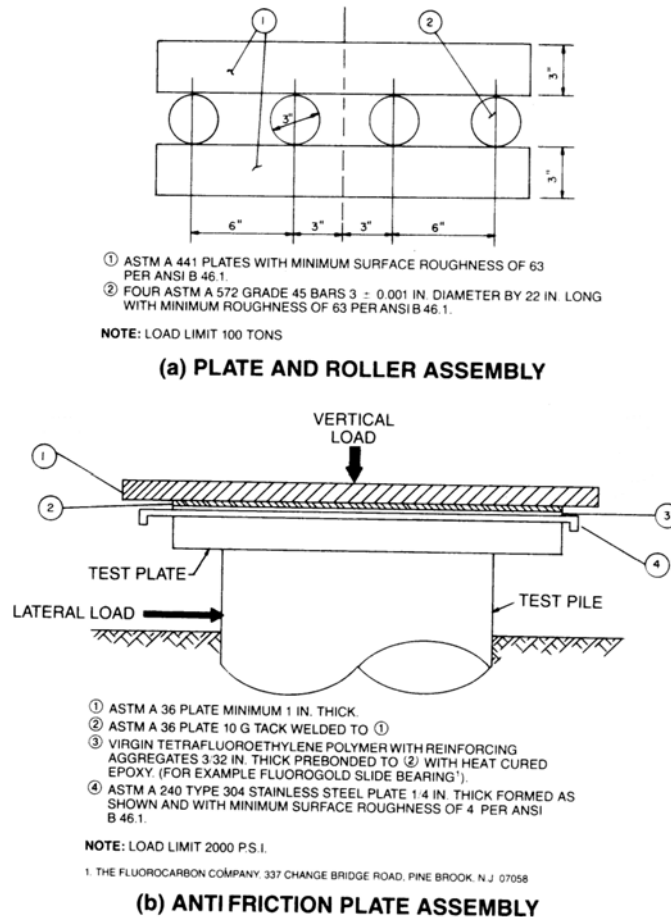


FIG. 8 Typical Anti-friction Devices for Combined Load Test

7.1.2 Reference beams shall have adequate strength, stiffness, and cross bracing to support the test instrumentation and minimize vibrations that may degrade measurement of the pile movement. One end of each beam shall be free to move laterally as the beam length changes with temperature variations. Supports for reference beams and wirelines shall be isolated from moving water and wave action. Provide a tarp or shelter to prevent direct sunlight and precipitation from affecting the measuring and reference systems.

7.1.3 Dial and electronic displacement indicators shall conform to ASME B89.1.10.M and should generally have a travel of 100 mm [4 in.], but shall have a minimum travel of at least 75 mm [3 in.]. Provide greater travel, longer stems, or sufficient calibrated blocks to allow for greater movement if anticipated. Electronic indicators shall have a real-time display of the movement available during the test. Provide a smooth bearing surface for the indicator stem perpendicular to the direction of stem travel, such as a small, lubricated, glass plate glued in place. Except as required in 7.4, indicators shall have minimum graduations of 0.25 mm [0.01 in.] or less, with similar accuracy. Scales used to measure pile movements shall have a length no less than 150 mm [6 in.], minimum graduations of 0.5 mm [0.02 in.] or less, with similar accuracy, and shall be read to the nearest 0.1 mm [0.005 in.]. Survey rods shall have

minimum graduations of 1 mm [0.01 ft] or less, with similar accuracy, and shall be read to the nearest 0.1 mm [0.001 ft].

7.1.4 Dial indicators and electronic displacement indicators shall be in good working condition and shall have a full range calibration within three years prior to each test or series of tests. Furnish calibration reports prior to performing a test, including the ambient air temperature during calibration.

7.1.5 Clearly identify each displacement indicator, scale, and reference point used during the test with a reference number or letter.

7.1.6 Indicators, scales, or reference points attached to the test pile, pile cap, reference beam, or other references shall be firmly affixed to prevent movement relative to the test pile or pile cap during the test. Unless otherwise approved by the engineer, verify that reference beam and wireline supports do not move during the test as provided in 7.6.

7.2 Pile Top Lateral Movements:

7.2.1 Unless otherwise specified, all lateral load tests shall include apparatus for measuring the lateral movement of the test pile top, or piles within a group, or the pile group cap. This apparatus as described herein shall include a primary measurement system and at least one redundant, secondary system.

NOTE 8—When possible use displacement indicators as the primary

system to obtain the most precise measurements. Use the redundant system(s) to check top movement data and provide continuity when the measuring system is disturbed or reset for additional movement.

7.2.2 Displacement Indicators (Fig. 1)—Orient the reference beam(s) perpendicular to the line of load application, placing the beam supports as far as feasible from the test pile, anchor piles, deadmen, or cribbing. Mount the displacement indicator(s) on the reference beams to bear on the pile top along the line of load application of the test pile, or pile cap, with stems parallel to the line of load application. Alternatively, mount two indicators on axisymmetric points equidistant from the center of the test pile, or pile cap, with the stems parallel to the line of load application to bear on the reference beam(s). When locating reference beam(s) on the side of the test pile, or pile cap, opposite a compressive load, or on the same side as tensile load application, allow sufficient clearance between the test pile or pile cap and the reference beam for the anticipated lateral movement of the pile or pile group.

7.2.3 Wireline, Mirror, and Scale (Fig. 9)—Orient a wireline perpendicular to the line of load application placing the wireline supports as far as feasible from the test pile(s), anchor pile(s), deadmen, or cribbing. The wireline shall include a weight or spring to maintain a constant tension force in the wire, so that, when plucked or tapped, the wireline will return to its original position. Use clean, uncoated steel wire with a diameter of 0.25 mm [0.01 in.] or less for the wirelines. Each wireline shall pass across, and remain clear of, a scale mounted on the test pile or pile cap parallel to the line of load application. Mount the scale on a mirror affixed to the test pile or pile cap and use the wireline as a reference line to read the scale. Use the mirror to eliminate parallax error in the scale reading by lining up the wire and its image in the mirror. Align the wire not more than 13 mm [0.5 in.] from the face of the scale. When locating a wireline on the side of the test pile, or pile cap, opposite a compressive load, or on the same side as tensile load application, allow sufficient clearance between the test pile or pile cap and the wireline for the anticipated lateral movement of the pile or pile cap.

7.2.4 Surveyor's Transit and Scale—Mount a scale parallel to the line of load application on the side or top of the test pile or pile cap and readable from the side. Establish outside of the immediate test area a permanent transit station and a permanent backsight or foresight reference point on a line perpendicular to the line of load application and passing through the target scale.

Take readings of lateral movement on the target scale using a surveyor's transit referenced to the fixed backsight or foresight.

7.2.5 Other Types of Measurement Systems (Optional)—The engineer may specify another type of measurement system satisfying the basic requirements of 7.2.

7.3 Rotational Movement (Optional) (Fig. 10)—Measure the rotation of the head of the test pile using a steel extension member firmly attached to, or embedded in, and in axial alignment with the test pile, and extending a minimum of 0.6 m [2 ft]. Mount the displacement indicator(s) on a reference beam with the gauge stem(s) parallel to the line of load application and bearing against the side of the extension member near its top (Fig. 10a). Measure the rotation of a pile cap by either (1) readings on reference points located on top of and at opposite ends of the pile cap in the line with the load application and obtained with either displacement indicators mounted on an independent reference system, or a surveyor's level to read either a target rod or vertical scales with reference to a fixed bench mark; or (2) a displacement indicator with its stem parallel to the line of load application and bearing against the side of the pile or pile cap, or a suitable extension thereto, and mounted on a reference beam a minimum of 0.6 m [2 ft] vertically above the displacement indicator used to measure the lateral pile top movement (Fig. 10b). For fixed-head tests on individual piles, use the apparatus for measuring rotation of free-head tests except that the upper displacement indicator may bear against the pile or measure the vertical movements at the ends of the steel frames using either a displacement indicator or a surveyor's level with a target rod or vertical scale (Fig. 10c).

7.4 Vertical Movement (Optional)—Measure the vertical movements of the test pile(s) or pile group in accordance with Test Method D1143 except that only one measuring system shall be required. For a test on an individual pile a single reference point on the pile is sufficient. For a test on a pile cap, take readings on two reference points on opposite sides of the pile cap and in line with the applied load.

7.5 Side Movement (Optional)—Measure the movement of the test pile(s) or pile group in a direction perpendicular to the line of load application using either a dial gauge mounted on a reference beam with the gauge stem bearing against the side of the pile or pile cap or a scale mounted horizontally on the pile or pile cap perpendicular to the line of load application and

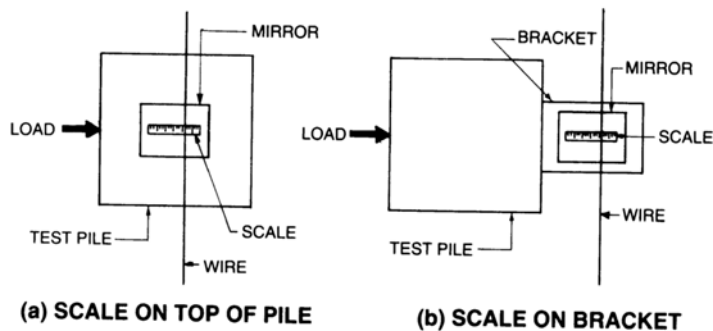


FIG. 9 Typical Wire-Scale Arrangements to Measure Lateral Deflections (Top Views)

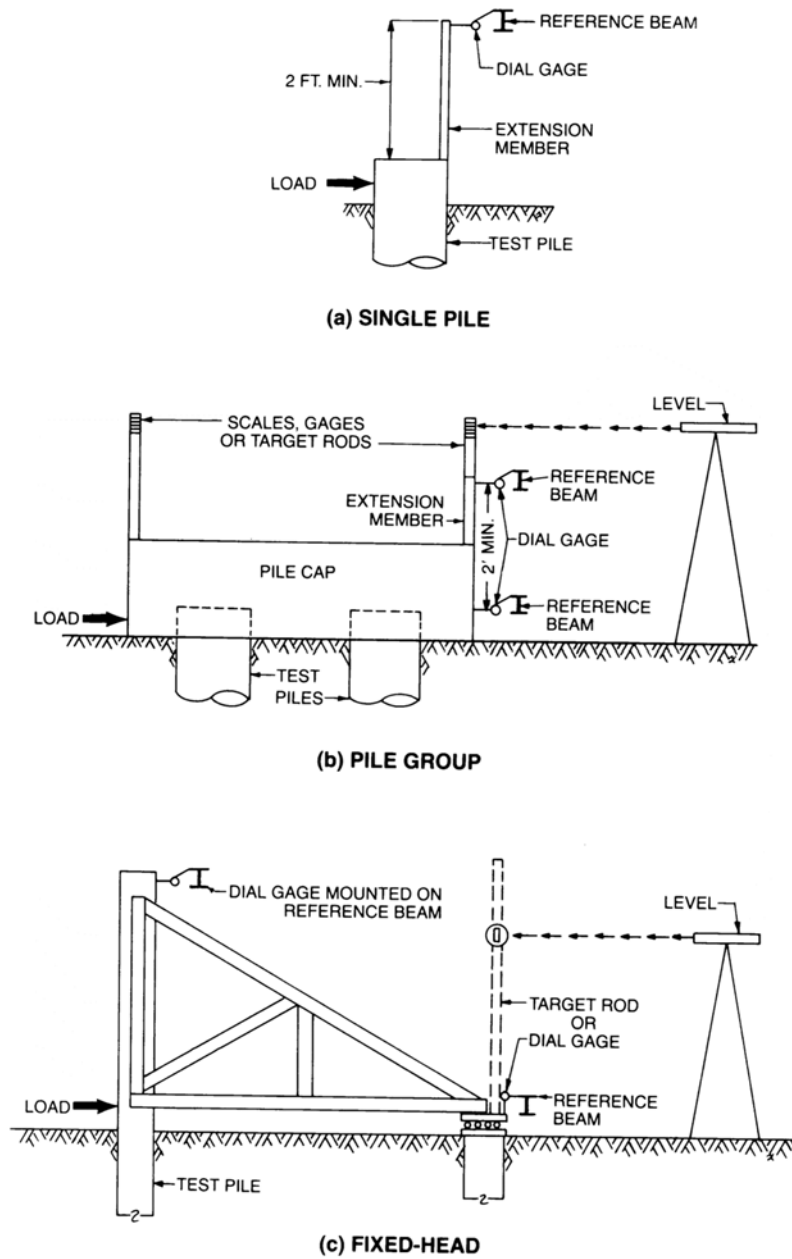


FIG. 10 Typical Arrangements for Measuring Pile Head Rotation

read with an engineer's transit set up at a fixed position with the line of sight referenced to a fixed foresight or backsight.

NOTE 9—The measurement of vertical and side movements of the test pile under lateral loading may reveal eccentric loading or an abnormal behavior of the test pile. Such measurements are recommended if the precise response of the test pile to the lateral test load is required.

7.6 Movement of Testing Apparatus:

7.6.1 *Lateral Movements*—Measure the movements along the line of load application of the reference beam(s) and reaction system using either a surveyor's transit reading target scales attached to the reference beam(s) and the reaction system at strategic locations along the line of load application or displacement indicators suitably mounted and referenced.

For transit readings, establish permanent transit stations and fixed backsights or foresights outside of the immediate test area.

7.6.2 *Vertical Movement (Optional)*—Measure vertical movements of the reference beam(s) and reaction system using a surveyor's level reading and a target rod or vertical scale located at strategic reference points along the line of load application. Reference level readings to a fixed benchmark located outside of the test area.

7.7 *Axial Deflections (Optional)*—Install in or on the test pile(s) to the depth(s) specified, tubing or ducts suitable to accommodate the types of inclinometer specified to be used.

NOTE 10—Except for very short stiff piles, inclinometer measurements are generally not warranted for the full length of the pile. Generally such measurements can be limited to the upper third or half of the pile length. The project specifications should clearly indicate the contractor’s responsibility for providing this instrumentation system as appropriate including materials, installation, equipment, and use.

7.8 *Strain Measurements (Optional)*—Measure the strain of the test pile(s) during loading at locations specified by the engineer to help evaluate the distribution of load transfer from the pile to the surrounding soil. Measure pile strain directly using strain gauges installed along the length of the pile axis. Install the gauge in pairs to measure axial strain, with the gauges in each pair located at the same depth, symmetrically opposite each other, equidistant from and parallel to the pile axis, and in line with the applied load. Measure and record the distance from the pile top to the gauges to the nearest 10 mm [0.5 in.]. The gauge type and installation shall be as specified by the engineer and shall include temperature compensation as recommended by the gauge manufacturer. Where feasible, measurement programs involving strain gauges should include calibration of the fully instrumented pile and a complete history of gauge readings starting before their installation in the pile.

NOTE 11—To interpret strain measurements and estimate pile stresses, the engineer will require a depth profile describing the variation of pile constituents and their strength, cross sectional area, and stiffness. Stiffness properties may vary with the applied stress, especially for grout or concrete. Obtain this information from installation records and separate material property tests as needed.

8. Test Procedures

8.1 *Loading:*

8.1.1 *General:*

8.1.1.1 Apply test loads following one of the procedures described below for each test method, or as modified by the engineer. If feasible, the maximum applied load should reach a failure that reflects the ultimate axial static tensile load capacity of the pile(s). Do not exceed the safe structural capacity of the pile or pile group, or the loading apparatus. Do not leave a loaded pile unattended.

8.1.1.2 To avoid excessive creep and possible structural failure of cast-in-place concrete piles, delay load testing after concrete placement to permit the fresh concrete to gain adequate strength and stiffness. Use test cylinders or cores of the pile concrete to determine the appropriate wait time, recognizing that the test cylinders will generally cure more quickly than concrete in the pile.

8.1.1.3 When temporarily dewatering a test site with piles installed in granular soils, maintain the groundwater level as near to the ground surface as possible and record the groundwater surface elevation during the test. Correct the axial pile capacity for the difference in groundwater level as judged appropriate, but generally only when the difference exceeds 1.5 m [5 ft].

8.1.2 *Procedure A: Standard Loading*—Unless failure occurs first, apply and remove a total test load equal to 200 % of the proposed lateral design load of the pile or pile group as follows:

Percent of Design Load	Load Duration, min
0	—
25	10
50	10
75	15
100	20
125	20
150	20
170	20
180	20
190	20
200	60
150	10
100	10
50	10
0	—

NOTE 12—Consideration should be given to limiting the lateral test load to that which would produce a maximum specified lateral movement, established for safety and load stability reasons.

8.1.3 *Procedure B: Excess Loading (Optional)*—After applying and removing the standard test load in accordance with 8.1.2 (and 8.1.4 for standard loading if applicable), apply and remove the additional specified test loads in accordance with the following table:

Percent of Design Load	Load Duration, min
0	10
50	10
100	10
150	10
200	10
210	15
220	15
230	15
240	15
250	15
etc. to maximum load specified in 10 % increments	etc. at 15 min intervals
max	30
75 max	10
50 max	10
25 max	10
0	—

8.1.4 *Procedure C: Cyclic Loading (Optional)*—Apply and remove the test load in accordance with the following table:

Standard Loading		Standard Loading	
Percent of Design Load	Load Duration min	Percent of Design Load	Load Duration min
0	—	75	10
25	10	0	10
50	10	50	10
25	10	100	10
0	10	150	10
50	10	170	20
75	15	180	20
100	20	190	20

Cyclic Loading Schedules Standard Loading			
Percent of Design Load	Load Duration min	Percent of Design Load	Load Duration min
50	10	200	60
0	10	150	10
50	10	100	10
100	10	50	10
125	20	0	—
150	20	—	—

Cyclic Loading Schedules Excess Loading ^A			
Percent of Design Load	Load Duration min	Percent of Design Load	Load Duration min
Follow standard cyclic loading schedule to 200 %		100	10
200	60	0	10
100	10	50	10
0	10	100	10
50	10	150	10
100	10	200	10
150	10	250	15
200	10	260	15
210	15	270	15
220	15	280	15
230	15	290	15
240	15	300	30
250	15	225	10
200	10	150	10
		75	10
		0	—

^A Schedule for 300 % maximum load. For loading in excess of 300 %, hold 300 % load for 15 min, follow loading and holding time pattern for additional loading and hold maximum load for 30 min.

8.1.5 Procedure D: Surge Loading (Optional):

8.1.5.1 General—Surge loading involves the application of any specified number of multiple loading cycles at any specified load level. Surge loading may be applied in conjunction with standard loading or after the completion of standard loading. Apply surge loads at a uniform rate by continuous activation of the hydraulic jack (or other power source) and remove the surge load at a uniform rate by continuous release of the power source.

8.1.5.2 Surge Loading with Standard Loading—Apply and remove the test load in accordance with the following table:

Surge Loading Schedule ^A with Standard Loading	
Percent of Design Load	Load Duration, min
0	—
25	10
50	10
75	15
100	20
50	10
0	10
100	—
0	—
100	—
0	—
50	10
75	10
100	10
125	20
150	20
75	10
0	10
150	—
0	—
150	—

Surge Loading Schedule ^A with Standard Loading	
Percent of Design Load	Load Duration, min
0	—
50	10
100	10
150	10
170	20
180	20
190	20
200	60
100	10
0	10
200	—
0	—
200	—
150	10
100	10
50	10
0	—

^A Schedule shown for two surges each at three load levels. If additional surges are specified or at other load levels follow the same loading and holding pattern.

8.1.5.3 Surge Loading After Standard Load—After applying and removing loads in accordance with 8.1.2, reapply the load to each specified load level and for the specified number of loading cycles, allowing sufficient time at each zero and peak load level for taking and recording the required load-movement data.

8.1.6 Procedure E: Reverse Loading (Optional)—Reverse loading involves the application of lateral test loads in either the push mode followed by the pull mode or vice versa. Test the pile or pile group in accordance with the loading schedule in 8.1.2-8.1.5 as specified first in one direction and then in the opposite direction.

8.1.7 Procedure F: Reciprocal Loading (Optional)—Apply and remove each specified lateral load level first in one direction and then in the opposite direction for the number of specified cycles. Hold each peak and zero load until load-deflection readings can be taken.

NOTE 13—Suitable apparatus is required to permit reversing the loads. Double-acting hydraulic cylinders are available in various sizes that can be activated by hand-operated, electric-powered, or air-hydraulic-powered pumps. Fig. 11 illustrates various possible setups for applying reverse and reciprocal loading. Reciprocal loads can be applied with a suitable powered crank and connecting rod system combined with a device to measure the applied loads.

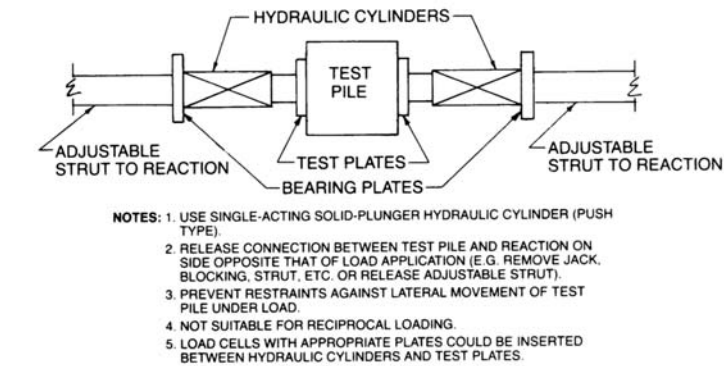
8.1.8 Procedure G: Specified Lateral Movement (Optional)—Apply the lateral test loads in accordance with 8.1.2-8.1.5 as specified until the gross lateral movement of the test pile or group is as specified and then remove the test load in four equal decrements allowing 10 min between decrements.

8.1.9 Procedure H: Combined Loading (Optional)—When the pile or pile group is tested under combined loading, in accordance with 6.7, apply the specified axial load before applying the lateral loads and hold the axial load constant during the application of the lateral loads in accordance with 8.1.2-8.1.5, or as specified.

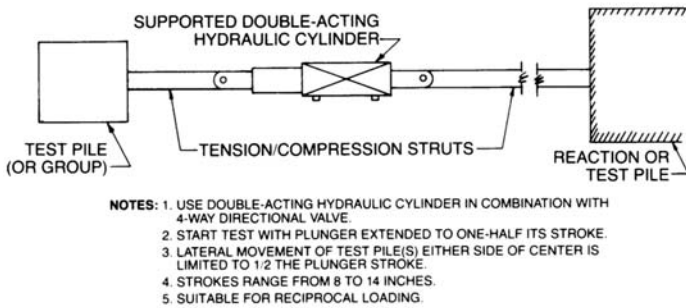
8.2 Recording Test Readings:

8.2.1 General:

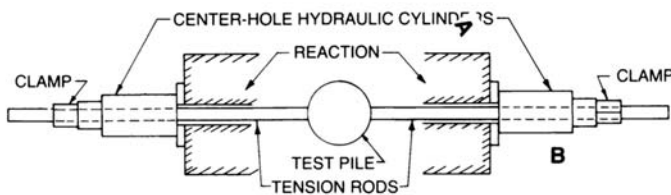
8.2.1.1 For the required time intervals described below for each test method, record the time, applied load, and movement readings (displacement, and if measured, axial deflection and



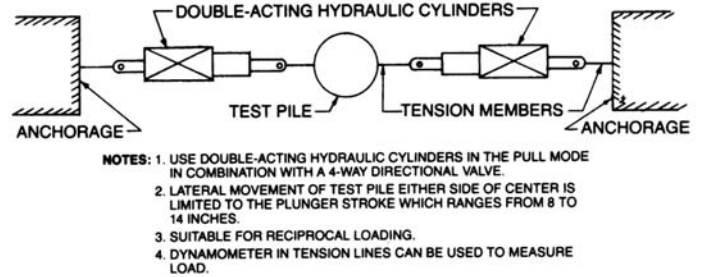
(a) WITH STANDARD HYDRAULIC CYLINDER



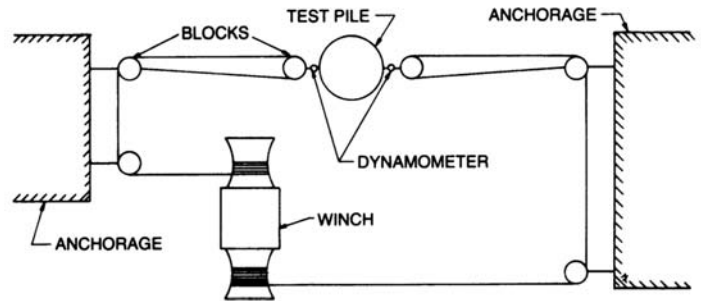
(b) WITH DOUBLE-ACTING HYDRAULIC CYLINDER



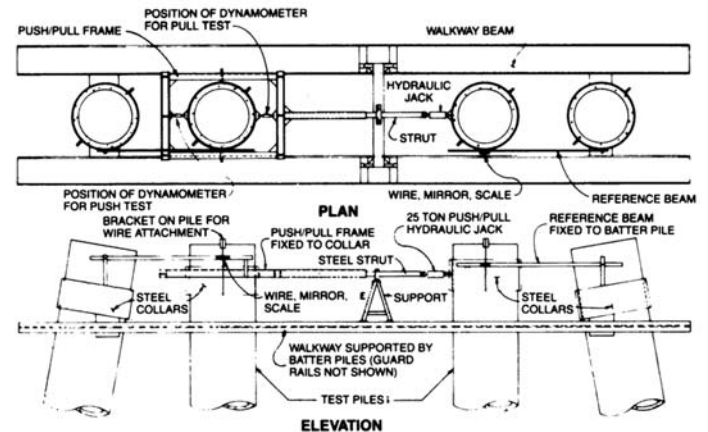
(c) WITH TWO CENTER-HOLE HYDRAULIC CYLINDERS



(d) WITH TWO PULL-TYPE HYDRAULIC CYLINDERS



(e) WITH TWO-DRUM WINCH



(f) WITH SPECIAL PUSH-PULL FRAME

(COURTESY RAYMOND INTERNATIONAL, INC.)

FIG. 11 Typical Reverse Lateral Loading Set-ups

strain) for each properly identified gauge, scale, or reference point taken as nearly simultaneously as practicable. The engineer may specify different reading intervals from those given below as needed to satisfy the objectives of a particular test pile program. Obtain additional test readings as specified by the engineer, or as convenient for testing purposes, that is, when using a datalogger to record readings at a constant time interval. Clearly record and explain any field adjustments made to instrumentation or recorded data.

8.2.1.2 Verify the stability of the reference beams and load reaction system (including reaction piles) using a surveyor's level or transit and target rod or scales to determine movement. Record readings taken before applying any test load, at the

proposed design load, at the maximum test load, and after the removal of all load. Intermediate readings for each load increment are recommended to provide additional quality assurance and detect potential failure of the load reaction system.

8.2.1.3 When using inclinometers to obtain axial deflection measurements as in 7.7, record the axial deflection just before starting the test and, as a minimum, at the end of each loading increment during the test.

8.2.1.4 When using embedded strain gauges to obtain incremental strain measurements as in 7.8, record strain readings just before starting the test and, as a minimum, during the test whenever recording readings of time, load, and movement. The

engineer may also require readings taken before and after the pile installation to obtain a complete strain history and investigate residual stress behavior.

8.2.2 *Procedure A, B, C, E, F, G, and H: Standard Measurement Intervals*—Record test readings immediately before and after the application of each load increment and the removal of each load decrement. Record additional test readings at 5-min intervals between load increments and load decrements. While the total test load is applied, record test readings at not less than 15-min intervals. Record test readings 15 min and 30 min after the total load have been removed. If pile failure occurs, record test readings immediately before removing the first load decrement.

8.2.3 *Procedure D: Surge Loading*—For initial application of test loads, for holding periods, for initial removal of the load and after removal of all loads, record the test readings in accordance with 8.2.2. For the surge loading, record test readings at the start and end of each load application.

8.2.4 *Rotational Movements*—When measuring rotational movements, record these test readings of immediately before and after the application of each load increment and the removal of each load decrement. Also record readings 30 min after removing the final test load.

8.2.5 *Vertical or Side Movements*—When measuring vertical or side movements, record these test readings before any test load is applied, at the proposed design load, at the maximum applied load, and after all loads have been removed. Intermediate readings for each load increment are recommended to provide additional quality assurance.

9. Safety Requirements

9.1 All operations in connection with pile load testing shall be carried out in such a manner so as 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:

9.1.1 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.

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

9.1.3 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 so as to avoid eccentric loading.

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

9.1.5 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.

9.1.6 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.

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

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

9.1.9 Only authorized personnel shall be permitted within the immediate test area, and only as necessary to monitor test equipment. As best as possible, locate pumps, load cell readouts, dataloggers, and test monitoring equipment at a safe distance away from jacks, loaded members (tension or compression), and their supports and connections.

10. Report

10.1 The report of the load test shall include the following information as required by the engineer and as appropriate to the pile type, test apparatus, and test method:

10.1.1 *General:*

10.1.1.1 Project identification and location,

10.1.1.2 Test site location,

10.1.1.3 Owner, structural engineer, geotechnical engineer, pile contractor, boring contractor,

10.1.1.4 Nearest test boring(s) or sounding(s), and their location with reference to test location,

10.1.1.5 In situ and laboratory soil test results, and

10.1.1.6 Horizontal and vertical control datum.

10.1.2 *Pile Installation Equipment:*

10.1.2.1 Make, model, type and size of hammer,

10.1.2.2 Weight of hammer and ram,

10.1.2.3 Stroke or ram,

10.1.2.4 Rated energy of hammer,

10.1.2.5 Rated capacity of boiler or compressor,

10.1.2.6 Type and dimensions of capblock and pile cushion,

10.1.2.7 Weight and dimensions of drive cap and follower,

10.1.2.8 Size of predrilling or jetting equipment,

10.1.2.9 Weight of clamp, follower, adaptor, and oscillator for vibratory driver,

10.1.2.10 Type, size, length, and weight of mandrel,

10.1.2.11 Type, size, and length of auger,

10.1.2.12 Type and size of grout pump,

10.1.2.13 Type, size, wall thickness, and length of drive casing,

10.1.2.14 Detailed description of drilling equipment and techniques, and

10.1.2.15 Size, type, length, and installation or extraction method of casings, or both.

10.1.3 *Test and Anchor Pile Details:*

10.1.3.1 Identification and location of test and anchor piles,

10.1.3.2 Design load of test pile or pile group,

10.1.3.3 Type and dimensions of test and anchor piles,

10.1.3.4 Test pile material including basic specifications,

10.1.3.5 Pile quality including knots, splits, checks and shakes, and straightness of piles, preservative treatment and conditioning process used for timber test piles including inspection certificates,

10.1.3.6 Wall thickness of pipe test pile,

10.1.3.7 Weight per foot of H test pile,

10.1.3.8 Description of test pile tip reinforcement or protection,

10.1.3.9 Description of banding—timber piles,

10.1.3.10 Description of special coatings used,

10.1.3.11 Test pile (mandrel) weight as driven,

- 10.1.3.12 Date precast test piles made,
- 10.1.3.13 Details of concrete design, grout mix design, or both.
- 10.1.3.14 Concrete or grout (or both) placement techniques and records,
- 10.1.3.15 Concrete or grout (or both) sample strengths and date of strength test,
- 10.1.3.16 Description of internal reinforcement used in test pile (size, length, number longitudinal bars, arrangement, spiral, or tie steel),
- 10.1.3.17 Condition of precast piles including spalled areas, cracks, top surface, and straightness of piles,
- 10.1.3.18 Effective prestress,
- 10.1.3.19 Degree of inclination for each pile,
- 10.1.3.20 Length of test pile during driving,
- 10.1.3.21 Final pile top and bottom elevations, and ground elevation referenced to a datum,
- 10.1.3.22 Embedded length—test and anchor piles,
- 10.1.3.23 Tested length of test pile, and
- 10.1.3.24 Final elevation of top of test pile referenced to fixed datum.
- 10.1.4 *Test and Anchor Pile Installation:*
 - 10.1.4.1 Date installed,
 - 10.1.4.2 Volume of concrete or grout placed in pile,
 - 10.1.4.3 Grout pressure used,
 - 10.1.4.4 Description of pre-excavation or jetting (depth, size, pressure, duration),
 - 10.1.4.5 Operating pressure for double-acting and differential type hammers,
 - 10.1.4.6 Throttle setting—diesel hammer (at final driving),
 - 10.1.4.7 Fuel type—diesel hammer,
 - 10.1.4.8 Horsepower delivered and frequency of vibratory driver during final 3 m [10 ft] of pile penetration,
 - 10.1.4.9 Description of special installation procedures used such as piles cased off,
 - 10.1.4.10 Type and location of pile splices,
 - 10.1.4.11 Driving or drilling records,
 - 10.1.4.12 Final penetration resistance (blows per centimetre [blows per inch]),
 - 10.1.4.13 Rate of pile penetration in m/s [ft/s] for last 3 m [10 ft], vibratory driving,
 - 10.1.4.14 When cap block replaced (indicate on log),
 - 10.1.4.15 When pile cushion replaced (indicate on log),
 - 10.1.4.16 Cause and duration of interruptions in pile installation, and
 - 10.1.4.17 Notation of any unusual occurrences during installation.
- 10.1.5 *Pile Testing:*

- 10.1.5.1 Date and type of test,
- 10.1.5.2 Temperature and weather conditions during tests,
- 10.1.5.3 Number of piles in group test,
- 10.1.5.4 Brief description of load application apparatus, including jack capacity,
- 10.1.5.5 Location of point of load application with reference to top of pile or pile cap, and to ground surface,
- 10.1.5.6 Description of instrumentation used to measure pile movement including location of indicators, scales, and other reference points with respect to pile top,
- 10.1.5.7 Description of special instrumentation such as inclinometers or strain gauges including location of such with reference to pile top,
- 10.1.5.8 Axial load—type, amount, how applied,
- 10.1.5.9 Special testing procedures used,
- 10.1.5.10 Tabulation of all time, load, and movement readings,
- 10.1.5.11 Tabulation of inclinometer readings, declination versus depth,
- 10.1.5.12 Identification and location sketch of all indicators, scales, and reference points,
- 10.1.5.13 Description and explanation of adjustments made to instrumentation or field data, or both,
- 10.1.5.14 Notation of any unusual occurrences during testing,
- 10.1.5.15 Test jack and other required calibration reports,
- 10.1.5.16 Groundwater level, and
- 10.1.5.17 Suitable photographs showing the test instrumentation and set-up.

11. Precision and Bias

11.1 *Precision*—Test data on precision is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site. Each test pile is unique due to the variable nature of the ground in which it is embedded. Furthermore, retesting a particular pile commonly results in different data from the initial testing due to plastic movement of the ground in which the pile is embedded.

11.1.1 The Subcommittee D18.11 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

11.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

12. Keywords

12.1 field testing; jack; lateral static pile capacity; load cell; loading procedure; reference beam

APPENDIX

(Nonmandatory Information)

X1. SOME FACTORS INFLUENCING INTERPRETATION OF TEST RESULTS

X1.1 Possible interaction of lateral loads from test pile(s) with lateral loads transferred to the soil from reaction piles or cribbing obtaining part or all of their support in soil at levels above the tip level of the test pile.

X1.2 Changes in pore water pressure in the soil caused by pile 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.

X1.3 Differences between conditions at time of testing and after final construction such as changes in grade or groundwater level.

X1.4 Loss or gain of test pile soil resistance due to changes in the soil stress distribution around the test pile(s) such as excavation, scour, fill, etc.

X1.5 Possible differences in the performance of a pile in a group or of a pile group from that of a single isolated pile.

X1.6 Affect on long-term pile performance of factors such as creep, environmental effects on pile material, negative friction loads, swelling soils, and strength losses.

X1.7 Type of structure to be supported, including sensitivity of structure to movement and relation between live and dead loads.

X1.8 Special testing procedures which may be required for the application of certain acceptance criteria or methods of interpretation.

X1.9 Requirement that non tested pile(s) have essentially identical conditions to those for tested pile(s) including, but not limited to, subsurface conditions, pile type, length, size and stiffness, and pile installation methods and equipment so that application or extrapolation of the test results to such other piles is valid.

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