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Standard Test Method for Individual Piles in Permafrost Under Static Axial Compressive Load[1]

This standard is issued under the fixed designation D 5780; 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.

INTRODUCTION

This test method has been prepared to cover methods of axial load testing of piles in permafrost. The provisions permit the introduction of more detailed requirements and procedures when required to satisfy the objectives of the test program. The procedures herein produce a relationship between applied load and pile settlement for conditions of ground temperature at the time of test. The results may be interpreted to establish long-term load capacity of piles in permafrost.

1. Scope

1.1 This test method covers procedures for testing individual vertical piles to determine response of the pile to static compressive load applied axially to the pile. This test method is applicable to all deep foundation units in permafrost that function in a manner similar to piles regardless of their method of installation. This test method is divided into the following sections:

NOTE 1—Apparatus and procedures designated "optional" are to be required only when included in the project specifications or 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, illustrations, and appendixes included herein are explanatory or advisory.

NOTE 2—This test method does not include the interpretation of test results or the application of test results to foundation design. See Appendix X1 for comments regarding some of the factors influencing the interpretation of test results. A qualified geotechnical engineer should interpret the test results for predicting pile performance and capacity.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.3 *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.* Specific precautionary statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

2.2 *ANSI Standard:*

B 30.1 Safety Code for Jacks[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The standard definitions of terms and symbols relating to soil and rock mechanics is Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adfreeze bond strength*—the strength of the bond developed between frozen soil and the surface of the pile.

3.2.2 *base load*—a load equivalent to the design load adjusted for test pile geometry and expected ground temperature.

3.2.3 *creep load*—that load applied to measure a rate of displacement.

3.2.4 *creep load increment*—an incremental load applied to a pile to determine the rate of displacement at 10 % of a failure load or at 100 % of a design load.

3.2.5 *design active layer*—the maximum depth of annual thaw anticipated surrounding the pile under design conditions.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.19 on Frozen Soils and Rock.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.2.6 *failure (in piles)*—pile displacement that is occurring at an increasing rate with time under the action of a constant load, incremental pile displacement that is increasing for uniform time increments, or a creep rate which exceeds 100 % of the design creep rate when loaded to 100 % of the design load.

3.2.7 *failure load*—that load applied to a pile to cause failure to occur.

3.2.8 *failure load increment*—the load increment applied to a pile that causes failure within a specified time period.

3.2.9 *freezeback*—for the purpose of this test method, freezeback shall be defined as the attainment of a subfreezing temperature at each ground temperature measuring point located below the design active layer, which have attained equilibrium with the surrounding soil.

3.2.10 *ice-poor*—frozen soil with a high solids concentration whose behavior is characterized mainly by soil particle contacts.

3.2.11 *ice-rich*—frozen soil with a moderate to low solids concentration whose behavior is characterized by ice particle contacts.

3.2.12 *pile, driven*—a pile driven into the ground with an impact or vibratory pile hammer.

3.2.13 *pile, grouted*—a pile placed in an oversized, predrilled hole and backfilled with a sand, cement grout.

3.2.14 *pile, slurried*—a pile placed in an oversized, predrilled hole and backfilled with a soil/water slurry.

3.2.15 *subfreezing temperature*—any temperature below the actual freezing temperature of the soil water combination being used.

3.2.16 *time to failure*—the total time from the start of the current test load increment to the point at which failure begins to occur.

4. Significance and Use

4.1 This test method will provide a relationship between time to failure, creep rate, and displacement to failure for specific failure loads at specific test temperatures as well as a relationship between creep rate and applied load at specific test temperatures for loads less than failure loads.

4.2 Pile design for specific soil temperatures may be controlled by either limiting long-term stress to below long-term strength or by limiting allowable settlement over the design life of the structure. It is the purpose of this test method to provide the basic information from which the limiting strength or long-term settlement may be evaluated by geotechnical engineers.

4.3 Data derived from pile tests at specific ground temperatures that differ from the design temperatures must be corrected to the design temperature by the use of data from additional pile tests, laboratory soil strength tests, or published correlations, if applicable, to provide a suitable means of correction.

4.4 For driven piles or grouted piles, failure will occur at the pile/soil interface. For slurried piles, failure can occur at either the pile/slurry interface or the slurry/soil interface, depending on the strength and deformation properties of the slurry material and the adfreeze bond strength. Location of the failure surface must be taken into account in the design of the test program and in the interpretation of the test results. Dynamic loads must be evaluated separately.

5. Installation of Test Pile(s)

5.1 Install the test pile according to the procedures and specifications used for the installation of the production piles.

NOTE 3—Because the pile behavior will be influenced by the soil type, temperature, ice content, and pore water salinity, the engineer must ensure that adequate information is available for soil/ice conditions at the construction site to determine their effect on the pile performance (that is, test pile should be installed in the same condition as the production piles—preferably at the same site).

5.2 The design and installation of the test pile shall address the effects of end bearing, as opposed to the shear resistance on the shaft of the pile. Address end bearing by measuring its effect, eliminating its effect, or accounting for its effect analytically. Measure end bearing by attaching a load cell to the tip of the pile prior to installation or by attaching a series of strain gages along the length of the pile prior to installation. Eliminate end bearing by attaching a compressible layer to the tip of the pile prior to installation or by providing a void beneath the tip of the pile.

5.3 Install thermistors or other temperature-measuring devices adjacent to the test pile to determine the ground temperature profile adjacent to the pile. Measure ground temperature in frozen ground at a minimum of three locations along the length of pile; for piles longer than 10 ft (3 m), it is recommended that ground temperatures be measured at 5-ft (1.5-m) depth intervals. Install the temperature-measuring devices in contact with the exterior pile surface; for slurried piles, installation may be as shown in Fig. 1; for driven piles, installation may be as shown in Fig. 2.

5.4 Measure ground temperatures periodically using the installed temperature-measuring devices to determine when freezeback occurs.

5.5 Where freezeback of soils adjacent to the pile is aided by the circulation of cold air or liquid coolant, discontinue such cooling when the measured ground temperatures become equal to the desired ground temperature for the pile test; significant overcooling shall not be permitted to occur. When freezeback of soils adjacent to the test piles is aided by a designed cooling system, such designed cooling system shall also be applied in a similar manner to all reaction piles to ensure freezeback of the reaction piles.

5.6 Isolate the surface of the test pile from the surrounding soil or ice over the depth of the design active layer. This may be accomplished by using a sleeve or casing. For slurried piles, a greased wrapping or other technique that will essentially eliminate the transfer of shear forces between the pile and the surrounding soil/ice in the design active layer may be used.

5.7 Where feasible, excavate the immediate area of the test pile or fill to the proposed finished grade elevation. Cut off test piles or build up to the proper grade necessary to permit construction of the load-application apparatus, placement of the necessary testing and instrumentation equipment, and observation of the instrumentation. Where necessary, brace the unsupported length of the test pile(s) to prevent buckling without influencing the test results.

5.8 If the top of the pile has been damaged during installation, remove the damaged portion prior to the test.

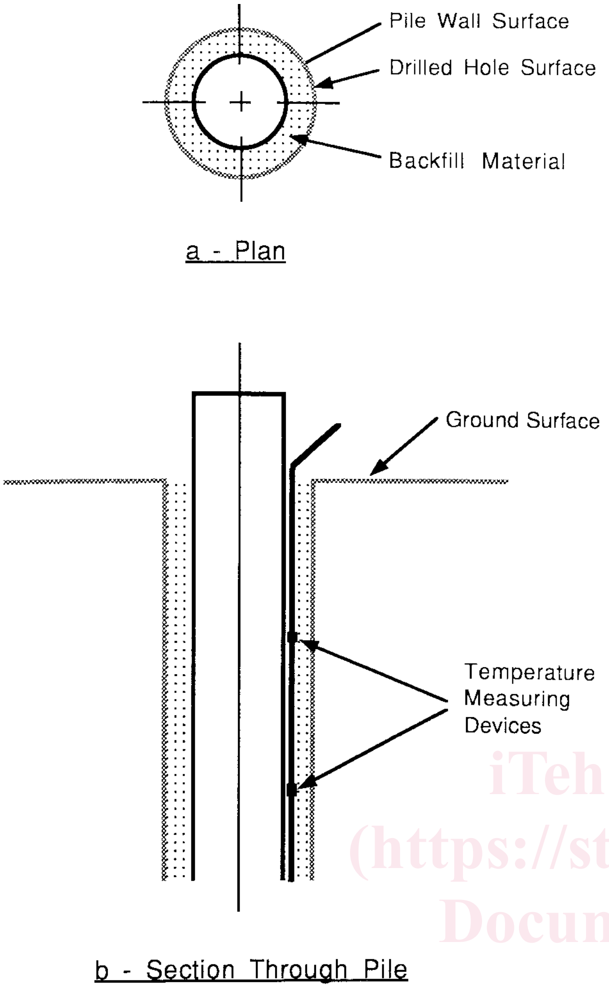

FIG. 1 Placement of Temperature Measuring Devices for Slurried Test Pile

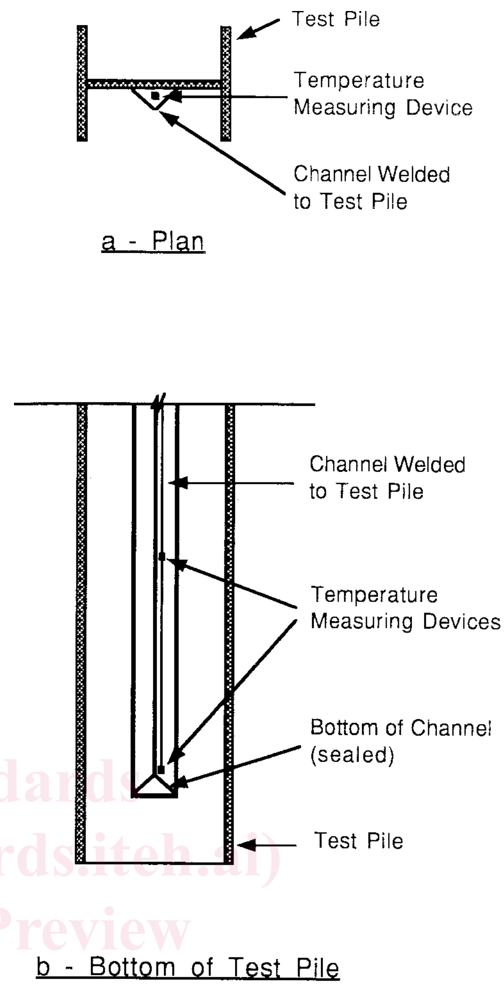

FIG. 2 Potential Placement of Temperature Measuring Devices for Driven Structural-Shaped Test Pile

NOTE 4—Consideration should be given to placing insulation on the ground surface around the test pile in order to reduce the variation in ground temperatures with time during the testing period. Where used, ground surface insulation should be placed all around the test pile to a distance of 5 ft (1.5 m), two times the depth of thawed soil or one third of the installed pile length, whichever is greater. The effect of insulation at the surface should be taken into account in the design of production piles, which could be done analytically.

5.9 Allow the lateral normal stresses between the pile surface and the surrounding soil that develop during pile installation or freezeback, or both, to dissipate to a nominal level prior to pile testing. For purposes of this test method, the delay time corresponding to the approximate test condition from Table 1 shall be permitted to occur prior to commencing load application to allow for the dissipation of normal stresses on the pile shaft as discussed above.

NOTE 5—The engineer may direct that delay times other than those shown in Table 1 be implemented, based on other completed pile test results, laboratory test results, or analytical results. Such other time interval shall allow for the dissipation of normal stresses developed due to pile installation or freezeback, or both, to a level of 1 % or less of their maximum value.

6. Apparatus for Applying Loads

6.1 *General*:

6.1.1 The apparatus for applying compressive loads to the test pile shall be as described in 6.3, 6.4, or 6.5, or as otherwise specified and shall be constructed so that the loads are applied to the central longitudinal axis of the pile to minimize eccentric loading. Subsections 6.3-6.5 are suitable for applying axial loads to individual vertical piles.

NOTE 6—Consideration should be given to providing sufficient clear space between the pile cap and the ground surface to eliminate any support of the cap by the soil. A properly constructed steel grillage may serve as an adequate pile cap for testing purposes.

6.1.2 For testing an individual pile, center a steel-bearing plate(s) on the pile and set perpendicular to the longitudinal axis of the pile. It shall be of sufficient thickness to prevent it from bending under the loads involved (but not less than 2 in.

TABLE 1 Minimum Delay Times (Days After Freezeback)

Permafrost Condition	Ground Temperature, − °F (°C)	Delay Times, Days	
		Driven Piles	Slurried Piles
Ice-poor	above 28 (−2)	10	14
	23 to 28 (−2 to − 5)	5	7
	below 23 (−5)	2	3
Ice-rich	above 28 (−2)	14	20
	23 to 28 (−2 to − 5)	7	10
	below 23 (−5)	5	7

(50 mm) thick). The size of the test plate shall be not less than the size of the pile top nor less than the area covered by the base(s) of the hydraulic jack(s).

6.1.3 For tests on precast or cast-in-place concrete piles, set the test plate, when used, in high-strength quick-setting grout. For tests on individual steel H-piles or pipe piles, weld the test plate to the pile. For tests on individual timber piles, the test plate may be set directly on the top of the pile that shall be sawed off to provide full bearing of the test plate, or alternatively, the test plate may be set in high-strength quick-setting grout.

6.1.4 In 6.3 and 6.4, center the hydraulic jack(s) on the test plate(s) with a steel-bearing plate of adequate thickness between the top(s) of the jack ram(s) and the bottom(s) of the test beam(s). If a load cell(s) or equivalent device(s) is to be used, center it on the bearing plate above the ram(s) with another steel bearing plate of sufficient thickness between the load cell(s) or equivalent device(s) and the bottom(s) of the test beam(s). Bearing plates shall be of sufficient size to accommodate the jack ram(s) and the load cell(s) or equivalent device(s) and properly bear against the bottom(s) of the test beam(s).

6.1.5 In 6.5, a test plate may be used in accordance with the appropriate provisions of 6.1 or, alternatively, the test beam(s) may be set directly on the pile cap or the loading material applied directly on the cap. Test beam(s) set directly on the cap shall obtain full bearing using high-strength quick-setting grout, if necessary.

6.2 *Testing Equipment*:

6.2.1 Hydraulic jacks including their operation shall conform to ANSI B30.1.

6.2.2 Unless a calibrated load cell(s) is used, calibrate the complete jacking system including the hydraulic jack(s), hydraulic pump, and pressure gage as a unit before each test or series of tests in a test program to provide an accuracy of less than 1 % of the applied load. Calibrate the hydraulic jack(s) over its complete range of ram travel for increasing and decreasing applied loads at a temperature within the air temperature range expected to occur during the load test. If two or more jacks are to be used to apply the test load, they shall be of the same ram diameter, connected to a common manifold and pressure gage, and operated by a single hydraulic pump.

NOTE 7—Where tests will be carried out in subfreezing fluctuating air temperatures, it is recommended that thermal insulation be applied to the hydraulic jack, the hydraulic lines, and other components of the loading system.

6.2.3 When an accuracy greater than that obtainable with the jacking system is required, use a properly constructed load cell(s) or equivalent device(s) in series with the hydraulic jack(s). Calibrate load cell(s) or equivalent device(s) prior to the test to provide an accuracy of less than 1 % of the applied load and equipped with a spherical bearing(s).

6.2.4 The hydraulic jack pump shall be equipped with an automatic regulator or accumulator to maintain the load within 1 % of the specified load as pile settlement occurs.

6.2.5 Furnish calibration reports for all testing equipment for which calibration is required, and show the temperature at which the calibration was done.

NOTE 8—Considerations should be given to employing a dual load-measuring system (jack pressure and load cell) to provide a check and as a backup in case one system malfunctions. Hydraulic jack rams should have sufficient travel to allow for anticipated pile settlements, deflections of the test beam, and elongation of connections to anchoring devices.

6.2.6 The use of a single high-capacity jack is preferred to the use of multiple jack(s). If a multiple jacking system is used, each jack should be fitted with a pressure gage (in addition to the master gage) in order to detect malfunctions.

6.3 *Load Applied to Pile by Hydraulic Jack(s) Acting Against Anchored Reaction Frame (see Fig. 3)*:

6.3.1 Install a sufficient number of anchor piles or suitable anchoring device(s) to provide adequate reactive capacity. Provide a clear distance from the test pile of at least five times the maximum diameter of the largest anchor or test pile(s) or 6 ft (2 m), whichever is greater.

6.3.2 Center a test beam(s) of sufficient size and strength over the test pile to avoid excessive deflection under load. Provide sufficient clearance between the bottom flange(s) of the test beam(s) and the top of the test pile for the necessary bearing plates, hydraulic jack(s) or load cell(s), or both, if used. For large test loads requiring several anchors, a steel framework may be required to transfer the applied loads from the test beam(s) to the anchors.

6.3.3 Attach the test beam(s) (or reaction framework if used) to the anchoring devices with connections designed to

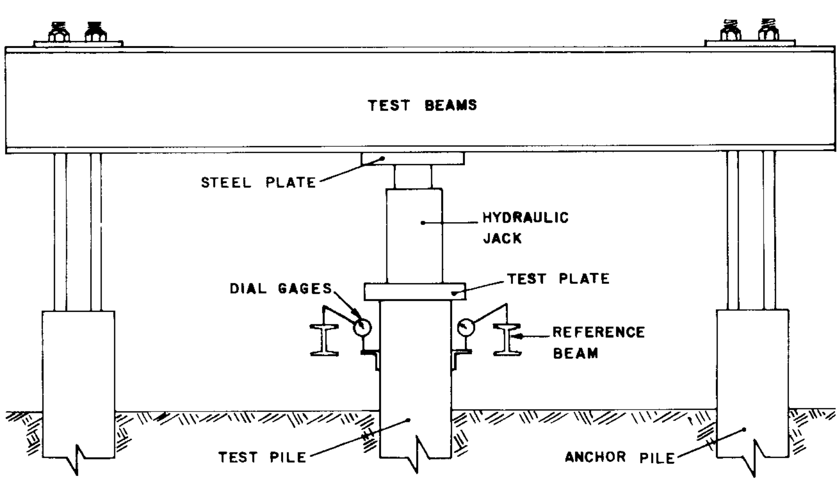

FIG. 3 Schematic Setup for Applying Loads to Pile Using Hydraulic Jack Acting Against Anchored Reaction Frame

adequately transfer the applied loads to the anchors so as to prevent slippage, rupture, or excessive elongation of the connections under the maximum required test load.

6.3.4 Apply the test load to the test pile with the hydraulic jack(s) reacting against the test beam(s) in accordance with the loading procedure in 8.1 or as otherwise specified.

6.4 *Load Applied to Pile by Hydraulic Jack(s) Acting Against a Weighted Box or Platform (see Fig. 4)*:

6.4.1 Center the test pile under a test beam(s) of sufficient size and strength to avoid excessive deflection under load allowing sufficient clearance between the top of the test pile or pile cap and the bottom(s) of the beam(s) after deflection under load to accommodate the necessary bearing plates, hydraulic jack(s), (and load cell(s) if used). Support the ends of the test beam(s) on temporary cribbing or other devices.

6.4.2 Center a box or platform over the test beam(s) with the edges of the box or platform parallel to the test beam(s) supported by cribbing or piles placed as far from the test pile as practicable but in no case less than a clear distance of 6 ft (2.0 m). If cribbing is used, the bearing area of the cribbing at ground surface shall be sufficient to prevent adverse settlement of the weighted box or platform. Insulation may be placed beneath the cribbing to mitigate the effects of thaw settlement.

6.4.3 Load the box or platform with any suitable material such as soil, rock, concrete, steel, or water-filled tanks with a total weight (including that of the test beam(s) and the box or platform) at least 10 % greater than the anticipated maximum test load.

6.4.4 Apply the test loads to the pile with the hydraulic jack(s) reacting against the test beam(s) in accordance with 8.1 or as otherwise specified.

6.5 *Load Applied Directly to the Pile With Known Weights (see Fig. 5)*:

6.5.1 Center on the test plate or pile cap a test beam(s) of known weight and of sufficient size and strength to avoid excessive deflection under load with the ends supported on temporary cribbing if necessary to stabilize the beam(s). Alternatively, the known test weights or loading material may be applied directly on the pile or pile cap.

6.5.2 Center and balance a platform of known weight on the test beam(s) or directly on the pile cap with overhanging edges of the platform parallel to the test beam(s) supported by cribbing or by piles capped with timber beams, so that a clear distance of not less than 6 ft (2.0 m) is maintained between the supports and the test pile or pile group.

6.5.3 Place sufficient pairs of timber wedges between the top of the cribbing or timber cap beams and the bottom edges of the platform so that the platform can be stabilized during loading or unloading.

6.5.4 When the platform is ready to load, remove any temporary supports at the ends of the test beam(s) and tighten the wedges along the bottom edges of the platform so that the platform is stable. Load the platform in accordance with the standard loading procedures in 8.1 or as otherwise specified using material such as steel or concrete so that the weight of incremental loads can be determined within 1 %.

NOTE 9—With the loading apparatus described in 6.5, provisions can be made for taking target rod level readings directly on the center of the pile or pile cap or center of the test plate to measure pile top movements as specified in 7.2.3. For tests on concrete piles, a hole is required in the center of the test plate through which would extend a steel pin embedded in the top of the pile or pile cap. For tests on steel or timber piles, readings would be taken on the test plate. To accommodate the target rod, a double test beam must be used with sufficient space between the beams and a hole must be left through the platform. To permit sighting on the target rod, it may be necessary to leave a space between the test weights in line with the line of sight.

6.6 *Other Types of Loading Apparatus (Optional)*—Any other type of loading apparatus satisfying the basic requirements of 6.3 or 6.4 may be used.

7. Apparatus for Measuring Movement

7.1 *General*:

7.1.1 All reference beams and wires shall be independently supported with supports firmly embedded in the ground at a clear distance of not less than 8 ft (2.5 m) from the test pile and as far as practical from the anchor piles or cribbing. Reference beams shall be sufficiently stiff to support the instrumentation such that excessive variations (± 0.0004 in. (± 0.01 mm)) in

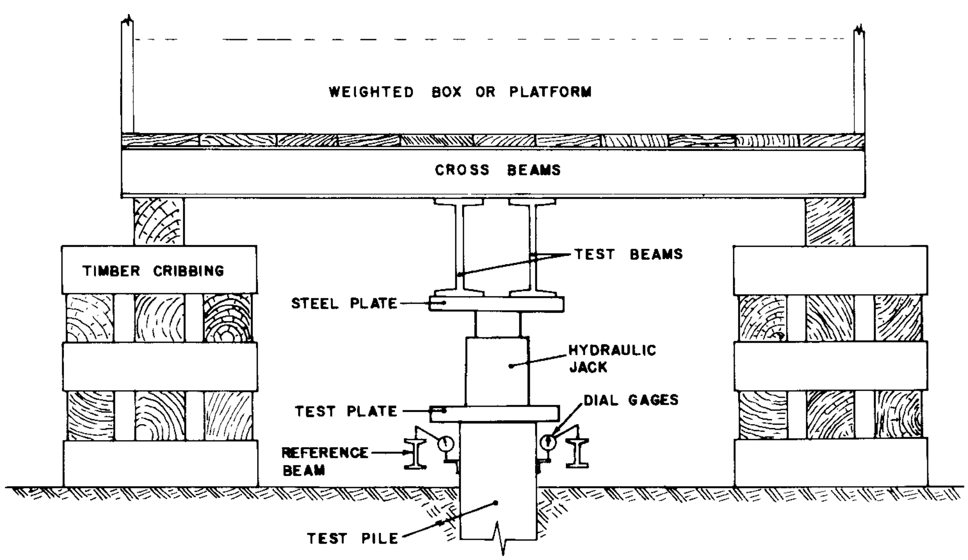

FIG. 4 Schematic Setup for Applying Loads to Pile Using Hydraulic Jack Acting Against Weighted Box or Platform

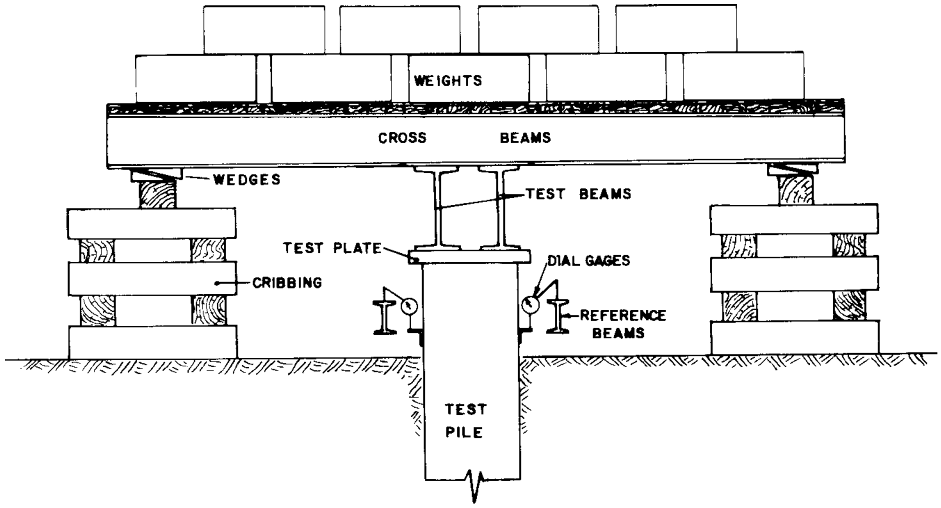

FIG. 5 Schematic Setup for Applying Loads Directly to Pile Using Weighted Platform

readings do not occur. If steel reference beams are used, one end of each beam shall be free to move horizontally as the beam length changes with temperature variations. Reference beams and the exposed length of the test pile shall be shielded from direct sunlight and exposure to the wind. Movement of the reference beams due to ambient temperature variations can be minimized through the addition of thermal insulation to the reference beams.

7.1.2 Reference and reaction beams shall each include one thermistor or other temperature-measuring device attached to each beam at or near the dial gage location or near the point of load application. The thermistor or other temperature-measuring device shall be located and attached in a manner which will allow the measurement of the temperature of the reference and reaction beams.

7.1.3 Dial gages shall have at least a 1-in. (25-mm) travel; longer gage stems or sufficient gage blocks shall be provided to allow for greater travel if anticipated. Gages shall have a precision of at least 0.0001 in. (0.0025 mm). Smooth bearing surfaces (such as glass) shall be provided for the gage stems perpendicular to the direction of gage-stem travel.

7.1.4 All dial gages, scales, and reference points shall be clearly marked with a reference number or letter to assist in recording data accurately. Provisions shall be made to protect the measuring system, reference system, and instrumentation from adverse temperature variation and from disturbance. All gages, scales, or reference points attached to the test pile or pile cap shall be mounted so as to prevent movement relative to the test pile cap or pile cap during the test.

7.1.5 Prior to commencement of the loading procedures detailed in 8.1, the movements of each reference beam with varying air temperature shall be measured during a 24-h calibration period. During this 24-h period, dial gage measurements and reference and reaction beam temperature measurements shall be taken concurrently at 30-min intervals and the test pile shall be subjected to a nominal load to seat the loading system on the top of the test pile. This nominal load shall be maintained at a constant value during the calibration load period. The data obtained during the calibration load period shall be used to develop a deflection correction curve for the measured reference beam temperature.

7.2 *Pile Top Axial Movements (see Fig. 6)*—The apparatus for measuring axial movement of the top of the test pile shall consist of a primary and secondary system in accordance with the following methods. The primary system shall consist of dial gages or other system with a precision of at least 0.0001 in. (0.0025 mm). The secondary system shall have a precision of at least 0.01 in. (0.25 mm).

NOTE 10—Two separate measuring systems are required in order to provide a check on the observed data, to provide for accidental disturbance of the measuring system, and to permit continuity of data in case it becomes necessary to reset the gages or scales.

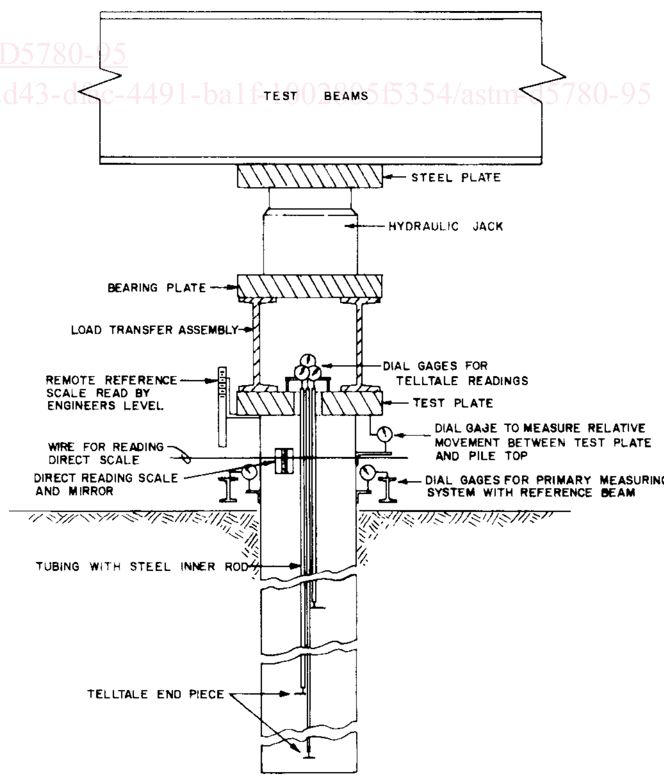

FIG. 6 Possible Arrangement of Instrumentation for Measuring Vertical Movements of Pile