Designation: D8232 – 18

# Standard Test Procedures for Measuring the Inclination of Deep Foundations[1]

This standard is issued under the fixed designation D8232; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 The test procedures described in this standard measure the inclination of deep foundation elements, including elements in the excavation stage. These Procedures apply to all deep foundations, referred to herein as "piles," regardless of their method of installation.

1.2 This standard provides minimum requirements for measuring the inclination of deep foundations. Plans, specifications, and/or provisions prepared by a qualified engineer may provide additional requirements and procedures as needed to satisfy the objectives of a particular test program.

1.3 This standard provides the following test Procedures:

| | |
|---|---|
| Procedure A (Inclinometer Testing)—for testing both open boreholes and constructed piles | 9.1 |
| Procedure B (Pendulum Testing)—for testing open boreholes | 9.2 |

1.4 Apparati and procedures herein designated "optional" may produce different test results and may be used only when approved by a qualified engineer (hereafter "the Engineer"). The word "shall" indicates a mandatory provision, and the word "should" indicates a recommended or advisory provision. Imperative sentences indicate mandatory provisions.

1.5 The Engineer shall design and approve the test configuration and test procedures.

1.6 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard. This standard also includes illustrations and appendices intended only for explanatory or advisory use.

1.7 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

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

1.9 The procedures used to specify how data are collected, recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

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

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

D6760 Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *battered pile or raked pile, n*—a pile purposely constructed at an inclination.

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

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3.2.2 *depth interval, n*—the spacing between measurements along the pile axis.

3.2.3 *deviation, n*—the distance and azimuth, measured on the horizontal plane, from the planned pile axis to the as-built axis at any given depth.

3.2.4 *inclination, n*—the angle, in either degrees or percent, between the vertical and the as-built excavation axis at any given depth, either measured directly or calculated.

3.2.5 *pile axis, n*—the line connecting the centroids of all horizontal cross sections of the pile.

3.2.6 *reference depth, n*—the vertical location that is determined to be (by survey) or assumed to be on location with the planned excavation axis. Typically the ground surface.

## 4. Summary of Test Method

4.1 *Procedure A*—In this Procedure, a probe equipped with a biaxial inclinometer (tiltmeter) is attached to a suitable centralizer. In open boreholes, the drilling bucket may serve as such a centralizer. The probe is gradually lowered to the bottom of the hole, and the inclination is measured at predetermined depth intervals. A portable digital device, connected to the probe via data cable or wireless connection, calculates the deviation of the pile axis by integrating the inclination over depth and then plots the results. An optional gyrocompass compensates for any rotation of the probe. When inclination is measured in access ducts, the probe shall be connected to a suitable centralizer that will assure the centricity of the probe while minimizing its rotation. The centralizer may be omitted if the access ducts are equipped with suitable means (for example, grooves) to keep the probe centered and prevent its rotation.

NOTE 1—When the drilling bucket is used as centralizer, the accuracy of the measurement depends on how closely it fits the open hole.

4.2 *Procedure B*—In this procedure a probe, suspended from a suitable conductor cable or attached to the drill rig Kelly bar, is first placed over the borehole axis at the reference depth. The probe, which is equipped with ultrasonic, laser, mechanical or other distance meters and a bi-axial inclinometer is then lowered down to the bottom of the hole. At predetermined depths or time intervals, the distances from the instrument to the sidewall are recorded in at least two perpendicular directions (for a minimum of four data points). The probe is connected to a portable digital device that plots the pile profile and calculates the deviation and/or the inclination of the pile.

## 5. Significance and Use

5.1 Piling specifications often prescribe the maximum allowable pile deviation from the planned inclination. Such a deviation can be the result of variable soil profile, a drilling rig that is inadequate for the job and/or faulty workmanship. There is evidence to show that loading a pile that exceeds the specified inclination can introduce excessive bending moments and shear forces if the pile was designed strictly for axial loads. In excavation support consisting of a contiguous piled wall or diaphragm wall, an excessive deviation may eventually decrease the available basement space or create undesired gaps in adjacent piles and permit seepage or ground loss. Efficient control of pile inclination is therefore of utmost importance.

NOTE 2—Measuring the excavation profile to infer the pile inclination has the additional benefit of enabling the contractor to estimate the actual volume of concrete that will be needed. In addition, knowledge of the finished pile profile may assist in the analysis of pile integrity tests and load tests.

## 6. Hazards

6.1 The test is carried out over open deep excavations that are often full with slurry and under mechanical equipment such as drilling rigs and/or cranes. 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.

## 7. Apparatus

7.1 *Signal transmission cable (optional)*—the cable shall be sufficiently robust to carry the probe and abrasion resistant to allow repeated field use and maintain flexibility in the range of expected temperatures. The cable itself, as well as all connectors, shall be waterproof to at least 150 % of the maximum testing depth. Alternatively, a wireless connection between the probe and the data recording and display unit may be established.

7.2 *Depth measuring device*—The cable shall be marked at regular intervals to assess depth of probe. Alternatively, a pulley over which the probe is deployed may be instrumented with a depth-encoding device to monitor the depth to the location of the probe throughout the test. The design of the pulley and cable reel shall be such that cable slippage shall not occur. Depth data may also be obtained from a rig-mounted depth meter or from a depth-sensing device incorporated in the probe.

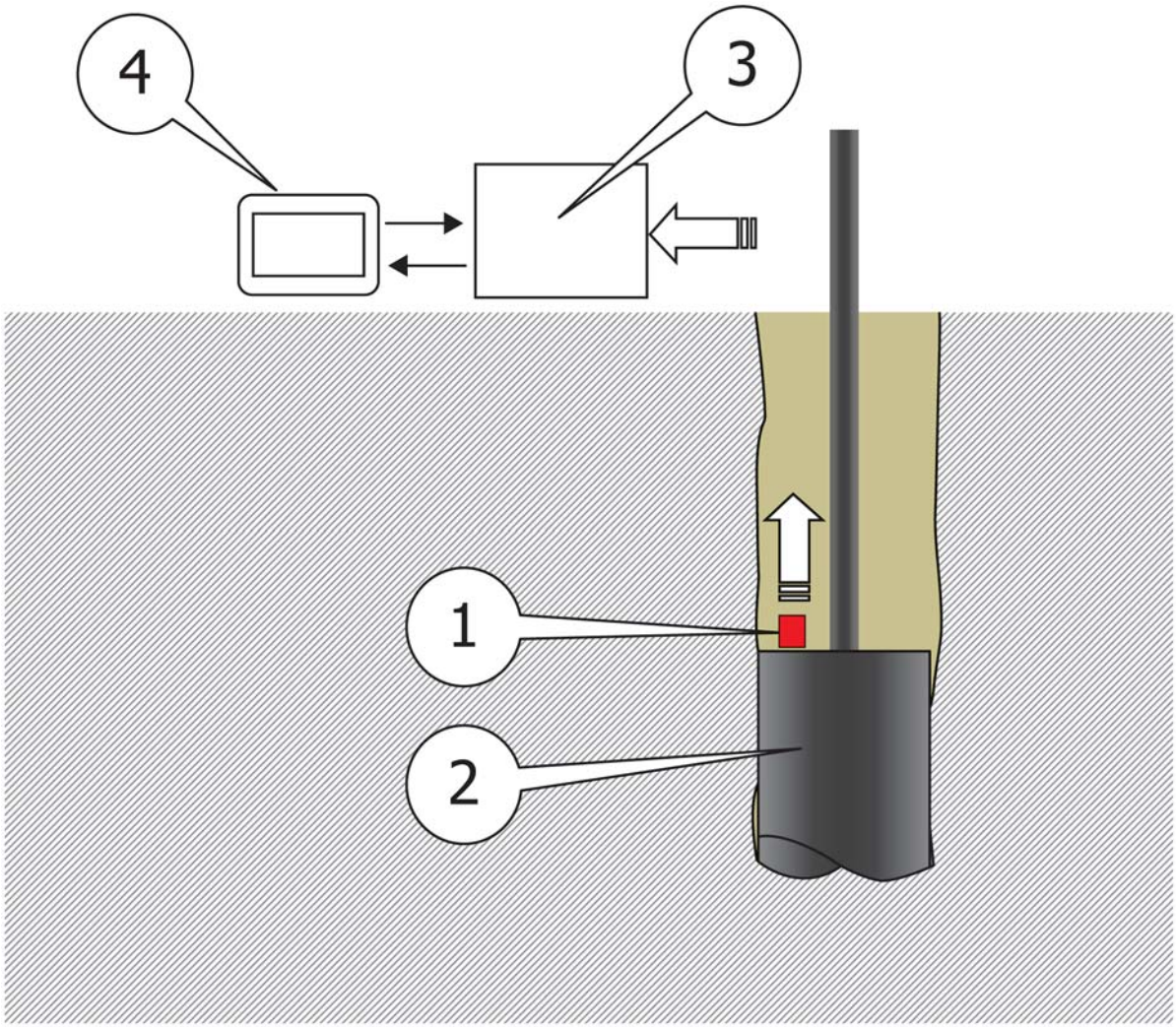
7.3 *Apparatus for recording, processing and displaying data*—The signals from the probe and the depth-measuring device shall be transmitted to a control box for handling the data and transmitting the results to a digital device for viewing and storing the results. Alternately, the data may be transmitted offsite from the probe to any location where the signals can be viewed and recorded remotely. The digital device may either be embedded in the control box or separate and may be equipped with a portable printer to produce hard copy of the results on site.

7.4 *Procedure A:*

7.4.1 *Probe*—The probe shall be designed to allow rigid attachment and quick detachment from the top of the centralizer. The probe housing shall be waterproof to at least 150 % of the maximum testing depth. A direction-indicating arrow shall be engraved on the probe to facilitate orientation. The probe shall be equipped with the following:

7.4.1.1 A bi-axial digital inclinometer, thermally-compensated and able to measure inclinations in two mutually-perpendicular directions.

7.4.1.2 A digital gyrocompass (optional), thermally-compensated and able to measure angles of rotation. A typical schematic arrangement of the testing apparatus is illustrated in Fig. 1.




(1 - Probe, 2 - Centralizer, 3 - Control Box, 4 - Digital Device)

**FIG. 1 Testing Appratus—Procedure A—Schematic Arrangement**

7.5 *Procedure B:*

7.5.1 *Probe*—If suspended by cable, the probe shall be sufficiently heavy to hang vertically even in thick drilling mud. The probe housing shall be waterproof to at least 150 % of the maximum testing depth. The probe shall be equipped with the following:

7.5.1.1 *A rotating sensor,* able to measure the distance to the sidewall at discrete angular steps. Alternatively, a minimum of four fixed ultrasonic or laser transceivers, able to measure the distance to the sidewall and oriented at equal angular spacings, may be used.

7.5.1.2 If probe is suspended on a single cable, a suitable means (gyrocompass, digital magnetic compass, set of orthogonal accelerometers or similar, henceforth referred to as "gyrocompass" in this document) to measure probe rotation around the vertical ("Z") axis.

7.5.1.3 Inclination sensors for verifying alignment and stability of the probe in the two horizontal axes.

7.5.2 *Winch or crane,* with sufficient capacity to carry the probe and cable from the center of the open hole, or an adapter for rigid attachment to the tip of the Kelly bar.

7.5.3 If suspended by cable, optionally a set of additional guide cables, sufficiently weighted at the bottom to maintain tension, may be deployed. The probe shall then include brackets to enable it to slide up and down the guide cables and prevent twisting and large-amplitude swinging of the probe. A typical schematic arrangement of the testing apparatus is illustrated in Fig. 2.

## 8. Calibration and Standardization

8.1 The inclinometer component of the probe shall be calibrated to an accuracy of 0.1 % throughout its full operational scale and temperature range, according to the manufacturer's instructions.

8.2 The depth-measuring device shall be field-calibrated at least once every six months to an accuracy of 2 % of the