



Designation: D6230 – 98(Reapproved 2005)

Standard Test Method for Monitoring Ground Movement Using Probe-Type Inclinometers¹

This standard is issued under the fixed designation D6230; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the use of inclinometers to monitor the internal movement of ground. The test method covers types of instruments, installation procedures, operating procedures and maintenance requirements. It also provides formulae for data reduction.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound 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 health and safety practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

D653 **Terminology Relating to Soil, Rock, and Contained Fluids**

D4622 **Test Method for Rock Mass Monitoring Using Inclinometers (Discontinued 2000)** (Withdrawn 2000)³

3. Significance and Use

3.1 An inclinometer is a device for measuring deformation normal to the axis of a pipe by passing a probe along the pipe and measuring the inclination of the probe with respect to the line of gravity. Measurements are converted to distances using trigonometric functions. Distances are summed to find the position of the pipe. Successive measurements give differences in position of the pipe and indicate deformation normal to the

axis of the pipe. In most cases the pipe is installed in a near-vertical hole. Measurements indicate subsurface horizontal deformation. In some cases the pipe is installed horizontally and the measurements indicate vertical deformation.

3.2 Inclinometers are also called slope inclinometers or slope indicators. Typical applications include measuring the rate of landslide movement and locating the zone of shearing, monitoring the magnitude and rate of horizontal movements for embankments and excavations, monitoring the settlement and lateral spread beneath tanks and embankments, and monitoring the deflection of bulkheads, piles or structural walls.

4. Apparatus

4.1 The probe type inclinometer uses sensors inside a probe to indicate the orientation of the probe relative to the pull of gravity. The complete system consists of:

4.1.1 A permanently installed pipe, called casing, with test method grooves. The casing is made of plastic, aluminum alloy, or fiberglass.

4.1.2 *The Probe*—Most probes use force balance accelerometers which give a voltage output that is proportional to inclination of the probe. Biaxial probes contain two sensors oriented 90° apart to permit readings in orthogonal directions at the same time.

4.1.3 A portable readout unit with power supply for the sensors and display to indicate probe inclination. The readout unit may have internal memory to record data.

4.1.4 An electrical cable connecting the probe and readout unit with distance markings. Fig. 1 shows a typical set of components.

5. Procedure

5.1 Installation of Casing in a Borehole:

5.1.1 Select casing materials that are compatible with the environmental conditions at the installation. Select casing size consistent with the specific measurement requirements and conditions for the job. Store casing materials in a safe, secure place to prevent damage. Sunlight may damage plastic casing. High and low pH may damage metal casing. Note that a special probe may be required for non-vertical boreholes.

5.1.2 Assemble all components required for the casing, including casing, joints, connectors, and end cap. Examine

¹ This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.23 on Field Instrumentation.

Current edition approved Nov. 1, 2005. Published December 2005. Originally approved in 1998. Last previous edition approved in 1998 as D6230 – 98. DOI: 10.1520/D6230-98R05.

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.



FIG. 1 Typical Components of Inclinometer System

backfill is preferable unless the surrounding ground is too pervious to hold the grout. Place grout with a tremie. Buoyancy must be overcome with grout backfills. Add a weight to the bottom of the inclinometer casing, temporarily place clean drill pipe inside the casing, or place the first 3 m (10 ft) of grout around the bottom of the casing and let it set, then complete the grouting. Place sand and gravel backfills slowly and with techniques to prevent leaving large voids in the backfill. Such voids can later lead to erratic readings. Place backfill and withdraw drill casing or augers in sequence to prevent any squeezing off of the borehole. Withdraw drill casing and hollow-stem augers without rotation to prevent damage to the inclinometer casing. Use measures to prevent backfill from spilling into the inclinometer casing.

5.2 Installation on The Ground Surface of Horizontal Casing:

NOTE 1—A practical limit for installing horizontal casing is about 100 m. Beyond 100 m cable friction makes it difficult to pull the inclinometer probe through the casing. Special TFE-fluorocarbon inserts on the cable alleviate the problem to some degree.

5.2.1 Select casing materials that are compatible with the environmental conditions at the installation. Select casing size consistent with the specific measurement requirements and conditions for the job. Store casing materials in a safe, secure place to prevent damage. Sunlight may damage plastic casing. High and low pH may damage metal casing. Note that a special probe is required for horizontal casing. If one end of the casing is to be buried then the end cap contains a pulley to carry a wire that is used to pull the probe into the inclinometer casing. Special care must be taken to insure that the pulley is correctly assembled, free to turn and has the wire in place. Take precautions at all times during installation to keep the wire clean.

5.2.2 Create a near-level surface over the length where the casing is to be installed. Cover with a bed of at least 50-mm (2-in.) deep and 300-mm (12-in.) wide of clean sand, pea gravel or a lean grout.

5.2.3 Assemble all components required for the casing, including casing joints, connectors, and end cap. Examine each component for defects. Do not use defective components since they may later cause problems with readings that are difficult to diagnose and impossible to correct. Keep all components clean and free of foreign matter during assembly. Follow the manufacturer's instructions for assembly of the casing. If required use sealing mastic and tape to seal all couplings to prevent later flow of soil particles into the casing. This is especially important when using grout to seal the casing in the borehole. Exercise care to keep the casing grooves free of obstructions. When assembling couplings, use procedures to prevent spiraling of the casing grooves. Twist adjacent couplings in alternate directions before fixing to minimize spiraling. Examine the casing during assembly to confirm that spiraling is not occurring.

5.2.4 Place the casing onto the bed and adjust its position until it is within the tolerances required by the readout device. Establish the reference orientation for the casing and align one set of grooves with this reference. This orientation is commonly referred to as the A direction. It aligns with the direction of

each component for defects. Do not use defective components since they may later cause problems with readings that are difficult to diagnose and impossible to correct. Keep all components clean and free of foreign matter during assembly. Follow the manufacturer's instructions for assembly of the casing. If required, use sealing mastic and tape to seal all couplings to prevent later flow of soil particles into the casing. This is especially important when using grout to seal the casing in the hole. Exercise care to keep the casing grooves free of obstructions. When assembling couplings, use procedures to prevent spiraling of the casing grooves. Twist adjacent couplings in alternate directions before fixing to minimize spiraling. Examine the casing during assembly to confirm that spiraling is not occurring. Place a cap on the bottom end and seal it to prevent inflow.

5.1.3 Create the borehole using procedures to keep it aligned within the range of the readout equipment. Extend the borehole at least 5 m (16 ft) beyond the zone of expected movement. It may be necessary to use casing, hollow-stem augers, or drilling mud to keep the hole open and stable. Flush the hole until clear of drilling cuttings.

5.1.4 Insert the casing into the borehole. Establish the reference orientation for the casing and align one set of grooves with this reference. This orientation is commonly referred to as the A direction. It should align with the direction of greatest anticipated movement. Add clean water to the casing if necessary to overcome buoyancy. Use care to minimize any twist of the casing during installation. Care should be exercised to maintain orientation without twisting from the first piece of casing to the last. Twisting the top of the casing may cause spiraling of casing at depth.

5.1.5 Backfill the annular space between the borehole wall and the inclinometer casing with a suitable filling material. Borehole can be pre-grouted or post-grouted. If post-grouted, grouting can be through a tremie placed in the annulus of the inclinometer casing and the borehole's walls or via an internal tremie connected to a one-way bottom grout valve. Options include cement grout, sand and pea gravel. A lean cement grout