



Designation: D 6230 – 98

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

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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:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 4622 Test Method for Rock Mass Monitoring Using Inclinometers²

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 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.

¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.23 on Field Instrumentation.

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



FIG. 1 Typical Components of Inclinometer System

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 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 Teflon 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 greatest anticipated movement. Visually check for and remove any spiraling. Determine that the pull cable is in position and moves freely through the inclinometer casing.

5.2.5 Use hand tools or light construction equipment to place clean sand, pea gravel or lean grout evenly, at least 150-mm (6-in.) wide, on both sides of the casing. Cover the inclinometer casing with at least 50 mm (2 in.) of clean sand,

pea gravel or lean grout. Place fill over casing in 150-mm (6-in.) lifts. Fill for the first lift should not contain any particles larger than 25 mm (1 in.). If compaction is required, use hand compactors for the first two lifts.

5.3 Calibration:

5.3.1 Inclinometers are factory calibrated and supplied with a calibration factor, K , that is specific to the probe and the readout unit. Some manufacturers provide standardized readout units that can be used with multiple probes. However it should be noted that electronic variations in the readout equipment may cause conditions where different probes will give different readings. It is recommended that a calibration check be performed any time a probe and readout unit combination is changed. For applications involving small but important changes over several years, recalibrate the instrument to the precision of the device at least once per year.

5.3.2 Perform a calibration check before each set of inclinometer readings. Field checks can be made using a test stand, a test casing, or a section of field casing in material that does not move. Test stands are available from most manufacturers. They employ a short piece of inclinometer casing preset at a fixed angle. The test stand must be set on a stable base and properly aligned by the manufacturer's instructions. A test casing is a short piece of casing installed in a fixed position with the grooves at angles of 0 to 10° from the vertical. A section of field casing that is placed in fixed material can be used to check calibrations. This last method is the least preferable since most field casings are near-vertical (or near-horizontal). Calibration checks on vertical casing can indicate malfunctioning equipment but cannot provide an accurate calibration.

5.3.3 Perform a calibration check by assembling the probe, cable and readout equipment and allowing it to equilibrate to ambient temperature for at least 10 min. The probe is positioned in the test stand or casing and readings taken. The probe is removed, rotated 90°, reinserted and read. This operation is repeated to obtain readings at 180 and 270°. Consult the manufacturer's instructions to determine if your readings are within the recommended ranges for the equipment. Any obvious malfunctioning of the equipment, such as drift in the reading with time, inability to reproduce a reading, should be corrected before using the instrument.

5.4 Measurement Method:

5.4.1 The probe is inserted into the casing oriented in the reference direction (that is, a direction) to the bottom of a vertical or inclined casing or to the far end of a horizontal casing. A measurement traverse is made by holding the probe stationary at each depth interval and recording depth and reading. Recommended practice is to use a reading interval equal to the wheel spacing on the probe. After each reading, raise the probe by the reading interval and take the next set of readings. Repeat the procedure to the top of the casing to complete the traverse. Remove the probe from the casing, rotate it 180°, and lower it to the bottom of the casing. Start readings for this traverse from exactly the same depth as the first traverse and make each reading at exactly the same depth as the first traverse. For biaxial probes, two traverses complete

the set of readings. For uniaxial probes, two more traverses must be made for the B direction the same way as for the A direction.

5.4.2 Check the set of readings by summing the readings for the A and A' directions at each depth and the readings for the B and B' direction. These sums are called check-sums and should equal a constant value that is a characteristic of the probe. Refer to the manufacturer's literature for information on allowable variation in the check-sum. A single deviation in a check-sum probably indicates a bad reading. Erratic behavior of the check-sums generally indicates a poor electrical connection or a malfunctioning probe or readout.

5.5 Initial Readings:

5.5.1 Make initial observations after allowing sufficient time for the grout around the casing to set or for the backfill to stabilize. Since computation of all displacements is based on the initial readings, it is important to have a valid set. Verify the initial set of readings with at least two sets of readings, taken on the same day. Check these readings for stability of the check-sums and for displacement within the accuracy of the equipment. Repeat observations until satisfactory agreement is obtained. From all initial readings taken, one set should be selected for use as the reference set for all subsequent readings. Take readings on any spiral with a spiral sensor if corrections for twist are desired, or if there is potential for twist in the casing of sufficient magnitude to affect the computed displacements of the casing.

5.5.2 The top position (x, y and z) of the inclinometer casing must be located by survey at the same time initial readings are made by survey to the accuracy of the inclinometer readings. Later changes in the top position of the casing can be used to check the inclinometer readings or to correct for movement of the bottom of the inclinometer casing.

5.6 Observations:

5.6.1 The frequency of observations depends upon the rate of movement and the allowable movements. Some installations may require several readings per day. Others may require a few readings per year. In uncertain conditions, inclinometer casings should be read frequently just after installation and the results used to adjust the interval of subsequent observations. Observations should coincide with the observations of other instrumentation, such as extensometers, piezometers, settlement devices, movement surveys, and the like.

5.6.2 The same procedure outlined for taking initial readings is used to take observations. It is essential that readings be taken at the same depths as used for the initial readings. It is generally desirable to use the same equipment, people and procedures for the same inclinometers to reduce systematic error. The check-sum should be examined after completing the readings for each inclinometer and repeat readings taken if any data are in question. Other data to be recorded with the initial readings include: ground surface elevation, date of installation, date of initial reading and elevation of bottom of casing.

5.7 Maintenance:

5.7.1 Check the wheel fixtures, bearings and springs frequently. Tighten and replace as necessary. Clean and lubricate guide wheels as recommended by manufacturer. For horizontal inclinometers using a pull wire, use a cloth to keep the pull