Designation: D6230 – 21ε1

Standard Practices for Monitoring Earth or Structural Movement Using Inclinometers[1]

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.

ε1 NOTE—Minor corrections were editorially made throughout in July 2021.

1. Scope*

1.1 This standard covers the use of inclinometers to monitor the internal movement of ground, or lateral movement of subsurface structures. The standard covers types of instruments, installation procedures, operating procedures, and maintenance requirements. The standard also provides formulae for data reduction.

1.2 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 unless superseded by this standard.

1.2.1 The procedures used to specify how data are collected, recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should 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; 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 analytical methods for engineering design.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.4 This standard offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this standard may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.5 *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.*

1.6 *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:*[2]

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

D3966/D3966M Test Methods for Deep Foundations Under Lateral Load

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

D7299 Practice for Verifying Performance of a Vertical Inclinometer Probe

3. Terminology

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

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

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[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.

*A Summary of Changes section appears at the end of this standard

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *inclinometer casing, n*—a (typically segmented) pipe or casing with grooves specific for the type of inclinometer being used.

3.2.1.1 *Discussion*—Casing is typically made of plastic, aluminum alloy, or fiberglass.

3.2.2 *inclinometer probe, n*—an instrument comprised of a downhole probe which uses internal sensors to detect its own orientation relative to the force of gravity, with a wheel assembly for lowering into the inclinometer casing along the alignment grooves, connected by a cable to a readout or datalogger at the surface.

3.2.3 *in-place inclinometer gauge (IPI gauge), n*—an inclinometer probe which is designed to be installed at a fixed depth in an inclinometer casing, typically in an array of multiple units with known spacing and kept in place for the duration of the monitoring period.

3.2.4 *spiral probe, n*—a wheeled probe that tracks alignment differences between its top and bottom wheels. whose readings measure the spiraling twist of an inclinometer casing installation.

4. Significance and Use

4.1 An inclinometer is a deformation monitoring system, which uses a grooved pipe or casing with internal longitudinal grooves aligned with the anticipated direction of movement, installed in either a soil/rock mass or a geotechnical structural element. The inclinometer casing can be surveyed with a single traversing probe or with an array of in-place inclinometer (IPI) gauges connected to a data logger. The measurement and calculation of deformation normal to the axis of the inclinometer casing is done by passing a probe along the length of this pipe or placement of a sensor array, guided by the internal grooves. The probe or sensor array measures the inclination of the pipe, usually in two orthogonal directions 90° apart (X- and Y-direction) with respect to the axis of the casing (Z-direction, usually the line of gravity). Measurements are converted to distances using trigonometric functions. Successive surveys compared with an initial survey give differences in position and indicate deformation normal to the axis of the inclinometer casing. In most cases the inclinometer casing is installed in a near-vertical hole, and the measurements indicate subsurface horizontal deformation. In some cases, the inclinometer casing is installed horizontally, and the measurements indicate vertical deformation.

4.2 Inclinometers are also called slope inclinometers or slope indicators. Typical applications include measuring the rate and direction 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.

NOTE 1—The precision of this standard 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. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Method A*—The traveling-probe-type inclinometer system consists of an inclinometer probe, typically utilizing microelectromechanical systems (MEMS) technology sensors, which give the inclination of the probe digitally. Biaxial probes contain two sensors oriented 90° apart to permit readings in orthogonal directions at the same time. Other sensor types, such as ones based on force balance accelerometers, which give a voltage output that is proportional to inclination of the probe, may also be used. The probe(s) can have an analog or digital output. Use of a single uniaxial or biaxial probe pulled through the casing while being sampled is designated as Method "A." A portable readout unit, connected via cable or wirelessly, is used to display probe inclination and record the inclination data.

5.1.1 An electrical cable with distance markings connects the probe and power supply (which may also include the readout). Fig. 1 illustrates a typical set of components. The cable should include a clamp to prevent the probe from falling down the borehole. For deep holes a hoist or winch may be required.

5.2 *Method B*—The in-place inclinometer (IPI) array is a set of gauges which are installed in the casing at fixed distances apart, using spacer rods or pipes. These gauges may be individual units with connecting and spacing elements between them, or may consist of a continuous assembly. Some models of in-place inclinometers may be held in plane using guide wheels in grooved casings. Fig. 2 illustrates two types of common in-place inclinometer assemblies. The left schematic in Fig. 2 is an example of multiple probes assembled together to form a single in-place inclinometer installation, with wheels to align in a grooved casing. Gauge length for this assembly is measured wheel to wheel. The right schematic in Fig. 2 is an example of a continuous in-place inclinometer with no wheels. Gauge length in this case is measured joint center to joint center. Use of an in-place inclinometer array which is sampled while stationary in the casing is designated as Method "B." Other sensor types, including ones mentioned in Method "A" above and also ones based on vibrating wire technology, may be used. The use of an array may be more applicable in a scenario where observations need to be taken relatively rapidly, such as during a lateral pile load test (see Standard D3966/D3966M), or where observations need to be taken continually over long periods of time, such as monitoring shoring for excess deformation during excavation. Individual instruments in the array may be uniaxial or biaxial.

6. Procedure

6.1 *Installation of Casing in a Borehole:*

6.1.1 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.

FIG. 1 Typical Components of Method A Inclinometer System

6.1.2 Assemble all components required for the casing, including casing, segments, couplings, 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 hole. Exercise care to keep any casing grooves free of obstructions. When assembling couplings, use procedures to prevent spiraling of the casing grooves. For grooved casings, 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.

6.1.3 Create the borehole using procedures to keep it aligned within the required tolerances for plumb, level, or horizontal location. Extend the borehole at least 5 m (16 ft) beyond the zone of expected movement if in soil, or 1.5 m (5 ft) into rock if bedrock is stable. It may be necessary to use drilling casing, a hollow-stem auger, or drilling mud to keep the hole open and stable. Flush the hole until clear of drilling cuttings.

6.1.4 Insert the casing into the borehole. Establish the reference orientation for the casing and, for grooved casing, align one set of grooves with this reference. This orientation is commonly referred to as the X direction. It should align with the direction of greatest anticipated movement (see Note 2). If the absolute direction of displacement is required, measure the angle between site plan north and the reference grooves in the casing using a magnetic compass or other survey methods. Add clean water to the inclinometer casing if necessary to help prevent buoyancy. Use of water alone will not overcome buoyancy created by fresh cement grout. See following section for guidance. Use care to minimize any twist of the casing during installation. Exercise care 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. For casings greater than 50 m (165 ft) in length, the twist of the grooves along the casing shall be checked by independent measurements. Measurement of casing twist is commonly carried out by means of spiral probes.

NOTE 2—If the X grooves are not aligned with the actual maximum movement, both sensors detect the movement corroborating what the other is reading. Most commercially available software for reducing inclinometer readings will report the maximum movement and the direction.

6.1.5 Backfill the annular space between the borehole wall and the inclinometer casing with a suitable fill material. Options include non-shrink cement grout or cement-bentonite grout, sand (see Note 3) and pea gravel. The fill material shall not be stiffer than the surrounding material. The 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. 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 or earth anchor 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 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 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. Many manufacturers include a recommended grout mix based on soil consistency in their product literature which may be used as a guideline.

NOTE 3—Many practitioners contend that sand should never be used as backfill especially for installations in excess of 30 m (100 ft) in depth.

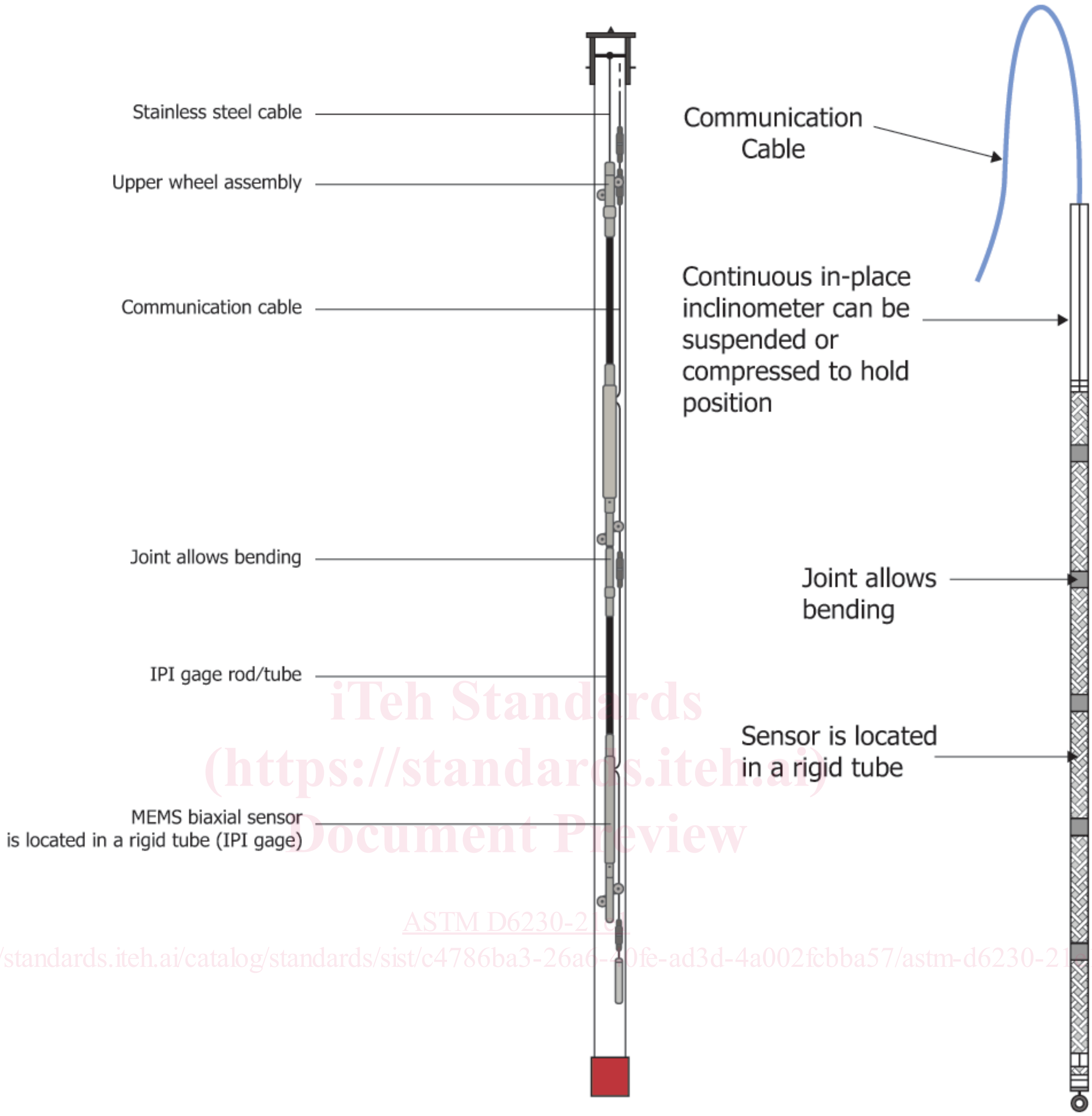

FIG. 2 Typical Components of Method B Inclinometer Systems

Sand placed by tremie often results in open voids as the sand bridges between the casing and borehole walls. In addition, the sand may settle resulting in drag on the casing that may deform or damage the casing.

6.2 *Installation on The Ground Surface of Horizontal Casing:*

6.2.1 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. Take special care to ensure 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.

NOTE 4—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.

6.2.2 Create a 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.

6.2.3 Assemble all components required for the casing, including casing couplings, 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 bed. 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.

6.2.4 Place the casing onto the bed and adjust its position until it is within the tolerances required by the readout device. For grooved casings, one set of grooves shall be aligned vertically (in line with the force of gravity). This orientation is commonly referred to as the X direction. Visually check for and remove any spiraling. Determine that the pull cable is in position and moves freely through the inclinometer casing.

6.2.5 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 shall not contain any particles larger than 25 mm (1 in.). If compaction is required, use hand compactors for the first two lifts.

6.3 *Equipment Verification:*

6.3.1 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, note that electronic variations in the readout equipment may cause conditions where different probes will give different readings. It is recommended that a verification 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 every two years. Note that a special probe may be required for non-vertical boreholes.

6.3.2 Perform a verification check before each set of inclinometer readings. in accordance with manufacturer's recommendations or Practice D7299. Verification checks on vertical casing can indicate malfunctioning equipment but cannot provide an accurate calibration.

6.3.3 Perform a verification check by assembling the probe, cable and readout equipment. Position the probe in the test stand or casing, allow it to equilibrate to ambient temperature for at least 10 min and then take a reading. Remove the probe, rotate 90°, reinsert, and take a reading. 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 or inability to reproduce a reading shall be corrected before using the instrument.

6.4 *Measurement Method A—Traveling-probe Inclinometer:*

6.4.1 Insert the probe into the casing oriented in the reference direction (that is, the 'X' direction) to the bottom of a vertical or inclined casing or to the far end of a horizontal casing. Allow probe to equilibrate to ambient temperature in the casing for at least 10 minutes. Complete a measurement traverse 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° (that is, the X' direction), and lower it to the bottom of the casing. Start readings for this traverse from the same depth as the first traverse and make each reading at 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 Y direction the same way as for the X direction.

6.4.2 Check the set of readings by summing the readings for the X and X' directions at each depth and the readings for the Y and Y' direction. These sums are called check-sums and should equal a constant low value that is a characteristic of the probe and casing installation. 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 or inaccurate depth positioning of the probe.

6.4.3 *Initial Readings:*

6.4.3.1 Make initial observations after allowing sufficient time for the grout around the casing to set, for the backfill to stabilize or prior to applying load to the structure. 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 shall be selected for use as the reference set for all subsequent readings. Do not average initial readings so as not to include any non-repeatable data. Compare data sets to ensure the system is stable, then use one set (usually the last set of readings taken) as the initial reading. 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.

6.4.3.2 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.

6.4.4 *Observations:*

6.4.4.1 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, read inclinometer casings frequently just after installation and use the results to adjust the interval of subsequent observations. Observations shall coincide with the observations of other instrumentation, such as extensometers, piezometers, settlement devices, or movement surveys.

6.4.4.2 The same procedure outlined for taking initial readings is used to take observations. It is essential to take readings 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 shall 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.

6.4.5 *Maintenance:*

6.4.5.1 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 wire clean at all times. Check the water seals on the electrical connections and replace as they become worn. Keep all electrical connections clean and dry. On probes using batteries, check the connections and charge as necessary. Consult the manufacturer's literature for instructions for maintenance operations and precautions, especially for removal of the battery if the device is not to be used for the next month. It is important to minimize dirt entering the casing, as it may accumulate in the casing grooves. It may become necessary to flush the inclinometer casing with water and use a large bottle brush to clean the grooves.

6.5 *Measurement Method B—Fixed-array Inclinometer:*

6.5.1 Follow manufacturer's recommendations on assembly and installation of inclinometer array. Depending on the type and length of the inclinometer array, due to the weight of a completed assembly, use a safety cable connected to the bottom of the array to assist in lowering and retrieving the array.

6.5.2 The theory of operation, data logging and analysis of an array of in-place inclinometers follows the general procedures for an individual inclinometer as outlined in 6.4 and Sections 7 and 8, with the exception that the instruments are left in place and do not move between observations. Often, the instrument array is read in only one orientation and not pivoted 180°, so the check-sum procedure would not be followed. The spacing between adjacent instruments L is typically constant for the entire array, but is not mandated to be so. Note the spacing between every level of instruments for use in Eq 1 to Eq 6 below.

7. Calculation

7.1 *General*—The numerical readings (R_X, R_Y, $R_{X'}$, $R_{Y'}$) are proportional to the deflection of the casing from the instrument's reference Z-direction (that is, vertical or horizontal). The casing deflection, d, equals:

$$d = \frac{L}{K} R \tag{1}$$

where: L is the reading interval and K is the instrument constant. K is supplied by the manufacturer and determined by factory calibration.

NOTE 5—Often the gauge length of the sensor's wheels is taken as the reading interval.

7.1.1 If using Method "A," average the readings in opposite directions (180° apart) to compute the incremental casing deflection at each depth:

$$d_{X-X'} = \frac{L}{K}\frac{(R_X - R_{X'})}{2} \qquad d_{Y-Y'} = \frac{L}{K}\frac{(R_Y - R_{Y'})}{2} \tag{2}$$

$d_{X-X'}$ is the computed incremental casing deflection at one depth in direction X–X', $d_{Y-Y'}$ is the computed incremental casing deflection at one depth in direction Y–Y'.

7.1.2 Compute the position of the casing at any depth n, D_n, as the sum of the incremental casing deflections from the end of the casing to that depth, or:

$$D_{n_{X-X'}} = \sum_{i=1}^{n} d_{i_{X-X'}} \qquad D_{n_{Y-Y'}} = \sum_{i=1}^{n} d_{i_{Y-Y'}} \tag{3}$$

Eq 3 assumes that the reference point is at the bottom of the casing.

7.1.3 Use Eq 3 with the initial set of readings to find the initial position of the inclinometer casing (see 6.4.3 for acquisition of initial reading).

7.1.4 Use Eq 3 with any subsequent set of readings to find the new position of the inclinometer casing at the time of the readings.

7.1.5 Use Eq 4 to compute the displacement of the casing ΔD_n between two times as the difference in position of the casing for those two times. It is usual practice for the readings at $t = t_0$ to be the initial set of readings.

$$\Delta D_{n_{X-X'}} = \sum_{i=1}^{n} d(t)_{i_{X-X'}} - \sum_{i=1}^{n} d(t_0)_{i_{X-X'}} \tag{4}$$

$$\Delta D_{n_{Y-Y'}} = \sum_{i=1}^{n} d(t)_{i_{Y-Y'}} - \sum_{i=1}^{n} d(t_0)_{i_{Y-Y'}}$$

7.1.6 If L and K are constant and the same for all sets of readings, Eq 4 can be simplified to Eq 5.

$$\Delta D_{n_{X-X'}} = \frac{L}{2K}\left[\sum_{i=1}^{n}\left(R_X(t) - R_{X'}(t)\right) - \sum_{i=1}^{n}\left(R_X(t_0) - R_{X'}(t_0)\right)\right] \tag{5}$$

$$\Delta D_{n_{Y-Y'}} = \frac{L}{2K}\left[\sum_{i=1}^{n}\left(R_Y(t) - R_{Y'}(t)\right) - \sum_{i=1}^{n}\left(R_Y(t_0) - R_{Y'}(t_0)\right)\right]$$

7.2 *Corrections for Twist (Spiraling)*—Computations of displacement must be corrected for twist where the inclinometer casing grooves are suspected to spiral. These corrections require readings of twist at each depth that inclinometer readings are taken. Usually, a separate probe is required to read twist. Readings are normally taken at the same time as initial readings.

Assuming twist is measured at each depth of deflection readings as the angle θ_i, the readings in the X–X' and Y–Y' directions are:

$$\Delta D_{i_g} = \sqrt{(\Delta D_{i_{X-X'}})^2 + (\Delta D_{i_{Y-Y'}})^2} \qquad \Delta D_{i_{X-X'}} = \Delta D_{i_g}\cot(\varphi_i + \theta_i) \tag{6}$$

$$\varphi_i = \tan^{-1}\left(\frac{\Delta D_{i_{Y-Y'}}}{\Delta D_{i_{X-X'}}}\right) \qquad \Delta D_{i_{Y-Y'}} = \Delta D_{i_g}\tan(\varphi_i - \theta_i)$$

where the angle of twist θ_i is positive in the clockwise direction.

7.3 *Adjustments for Surveyed Displacement*—In some cases the inclinometer casing cannot be practically installed into a fixed stratum. If the absolute displacements are required, then the position of one point on the casing must be determined by survey each time inclinometer readings are taken. This section assumes that the position of the top of the casing is determined by survey. From the survey determine the displacement in direction X–X' ($\Delta D_{s_{X-X'}}$) and Y–Y' ($\Delta D_{s_{Y-Y'}}$) since the initial readings. These values are added to the displacements determined in Eq 6 to find the total displacements of the inclinometer casing.

8. Report: Test Data Form

8.1 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. Report the results as a tabulation of displacement versus depth (see Fig. 3) and a plot of displacements versus depth (see Fig. 4) at various times and for both directions. If movement exists, a report of displacement at specific depth versus time is recommended (see Fig. 5). Even in situations where movement in the Y–Y' direction may be small or considered to be of no interest, these data are useful to indicate a malfunctioning instrument or defective casing or the occurrence of unexpected movements. Include the inclinometer number, project name, names of the personnel performing the testing and the equipment used (for example, make, model, serial numbers), orientation of reading directions, date of reading and date of initial reading on the report. Before these reports are created, the user shall use diagnostic plots (Profile, Incremental or Tilt, Tilt Change and checksums) to assure that the inclinometer surveys are of good quality and acceptable.

8.2 In specific cases the user may choose to use the diagnostic plots as part of the report if these plots have a point to make. For example, the incremental or tilt plot shows more effectively the elevation of a movement especially if there are more than one shear plane in the section crossed by the inclinometer pipe (see Fig. 6). The report shall also include an electronic file with the inclinometer survey raw data in case further analysis is needed.

NOTE 6—The historical axis naming convention for this standard is A–A' and B–B'; however, because this standard now presents two test methods, Method A and Method B, the committee has adopted the more traditional X–Y axis naming convention. Please note that commonly available data acquisition and reporting software used within the industry may reflect use of A–A' and B–B' in place of the X–X' and Y–Y' axes, respectively.

9. Precision and Bias

9.1 *Precision*—Test data on precision is not presented due to the nature of this standard. 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.

9.1.1 Subcommittee D18.23 is seeking any data from the users of this standard that might be used to make a limited statement on precision.

9.2 *Bias*—There is no accepted reference value for this standard, therefore, bias cannot be determined.

10. Keywords

10.1 deformations; field instrumentation; horizontal movement; inclinometer