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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Rock Mass Monitoring Using Inclinometers[1]

This standard is issued under the fixed designation D 4622; 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 describes the use of inclinometers for rock mass monitoring, lists some available instruments, outlines operating techniques and maintenance requirements, and presents data reduction formulas.[2]

1.2 *This standard does not purport to address all of the safety problems, 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.*

2. Significance and Use

2.1 An inclinometer is a device for measuring the deviations perpendicular to the axis of a borehole. Deviations can be converted to displacements by trigonometric functions. Successive measurements enable the determination of the depth, magnitude, and rate of lateral movement of an unstable slope.

3. Apparatus

3.1 *Probe-Type Inclinometer*—Many types of inclinometers are available; however, the most commonly used is the probe type. This type consists of a control box and a probe attached to a cable which is lowered into a flexible casing in a borehole. In some probes, a cantilevered pendulum with resistance strain gages, vibrating wire, or inductive transducers is used to measure cantilever deflection. Other probes use the Wheatstone bridge principle, the servo accelerometer principle, or a differential transformer. The probe generally requires a special flexible casing with four interior grooves spaced at 90°. The electrical output from the probe is measured at the control box and converted to visual display, punched or magnetic tape, or graphic form. Fig. 1 shows a typical inclinometer installation.

4. Procedure

4.1 *Installation*:

4.1.1 Install the inclinometer casing in a near-vertical hole that intersects the zone of suspected movement. (Measurements in non-vertical holes can be made with some inclinometers; however, before planning such holes, check manufacturers' specifications to determine the limitations of the particular instrument being used.) Extend the hole at least 15 ft (4.5 m) beyond the zone of expected movement into soil or rock in which no movement is anticipated. Make allowance for loss of the bottom 5 ft (1.5 m) of the hole where sediment accumulation may occur. Hold casing in place with a sand backfill or a weak cement grout. Check casings over 50 ft (15 m) deep for twist (spiraling of the interior grooves) using commercially available equipment, since some of the casings may be received with a built-in twist which would cause considerable error in observations.

4.1.2 Inclinometer casings are commonly installed in either 5 or 10-ft (1.5 or 3.0-m) lengths and are available in either plastic or aluminum. Plastic casing joints are glued. Aluminum casings are coupled with aluminum couplings and riveted (see Fig. 2). Complete the installed casing using left and right twist in a compensating manner so that the grooves generally are in the same azimuth from top to bottom. For casings over 50 ft (15 m), consider metal saddles with steel cable support for reducing twisting. Take care to ensure that all joints are sealed since leakage can introduce fines into grooves and cause errors in readings or plug the casings. Joints can be sealed with caulking and taped. Greater installation details can be obtained from manufacturers' literature or from other sources.

4.1.3 Whether to use plastic or aluminum casing depends on the situation and the method used. Plastic casing can be damaged if exposed to sunlight.

4.2 *Observations*:

4.2.1 Make initial observations after allowing sufficient time for the grout around the casing to set or for the backfill to settle where sand or gravel is used. Since computation of all displacements is based on the position of the casing when installed, verify the initial casing position with at least two separate sets of observations. Check these observations closely to see that they agree within the accuracy of the inclinometer being used. Repeat observations until satisfactory agreement is obtained. When initial observations are made, the top of the casing should be located with respect to a point on the ground surface which is outside the zone of expected movement by conventional surveying means and its elevation determined.

4.2.2 The frequency of observations depends upon several factors, the most important of which is the rate of movement. It is necessary to read inclinometers frequently just after installation and, based on these results, to adjust the interval of observations. Observations should coincide with observations

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

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[2] For additional information see the *Rock Testing Handbook*, U.S. Corps of Engineers, Waterways Experiment Station, Vicksburg, MI, 1978.

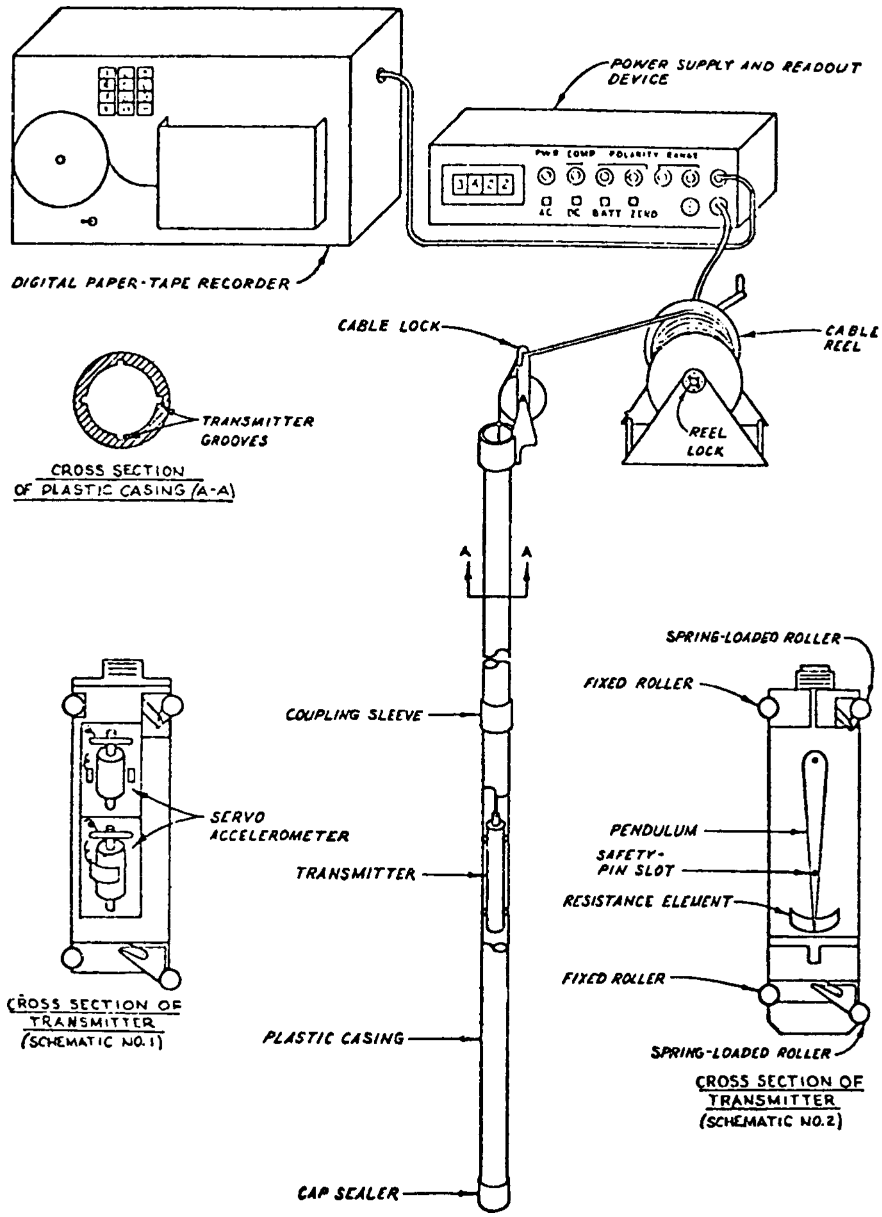

FIG. 1 Typical Inclinometer Installation

of other instrumentation, such as extensometers, piezometers, settlement devices, precipitation gages, movement surveys, and the like.

4.2.3 The procedure for obtaining readings with various inclinometers may vary slightly; consult manufacturers' literature for the current procedure for a particular instrument. However, the general procedure consists of lowering the inclinometer to the bottom of the borehole and beginning the readings, always ensuring that the inclinometer is lowered to the same depth as for the initial readings. Raise the inclinometer a specified interval, (greatest accuracy is obtained when the interval of observation equals the wheel spacing of the probe) make readings, and repeat the procedure until the top of the hole is reached. Remove the inclinometer from the casing, insert again with the guide wheels in the opposite groove (180° apart), lower to the bottom of the casing, and again make readings to the top of the hole. Repeat this procedure until four sets of readings are obtained; two readings for each pair of grooves. Make a field check by comparing the value of the sum of each set of readings (opposite grooves) and the mean of all sets of readings for the length of the casing. When variations greater than specified by the manufacturer are found, relocate the inclinometer at that depth and take an additional reading. Take care to ensure that readings are obtained at the same depths each time observations are made. Inability to observe at the exact depth each time can, to a large degree, be attributed to temperature variations which cause cable length changes.

4.3 *Maintenance*—Maintenance that can be performed in the field on inclinometers is very limited. On probes using" O" ring connections between the probe and the cable, check the" O" ring and replace as necessary. Keep electrical connections clean and dry. On probes using batteries, check the battery and

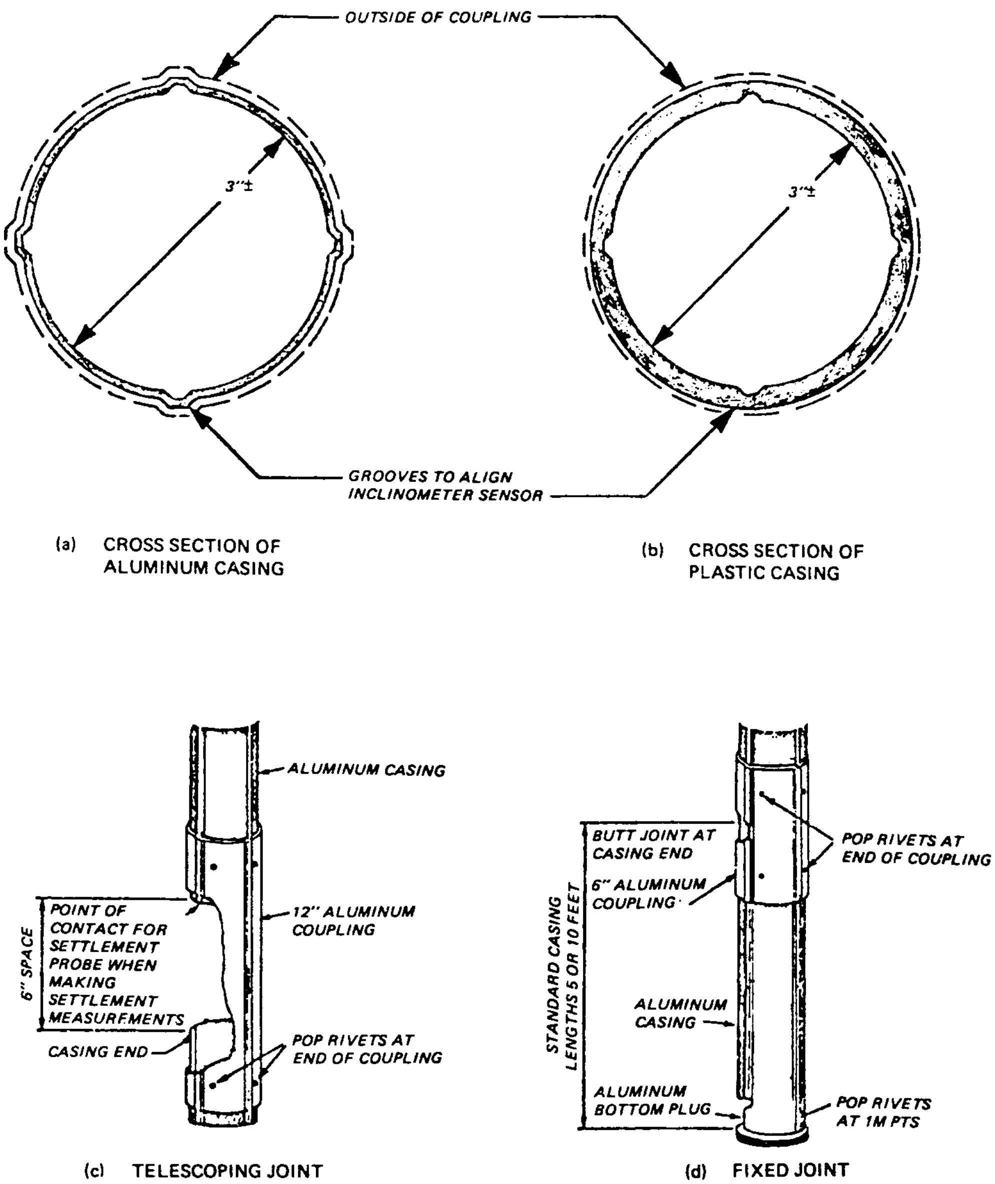

FIG. 2 Inclinometer Casing Details

charge when necessary. Consult manufacturers' literature for other maintenance operations and precautions to be exercised in the operation of inclinometers.

5. Calculations

5.1 *General*—The numerical values of the readings (*R*) obtained from observations with most inclinometers are equal to plus or minus an instrument constant (*K*) times the sine of the inclination angle (θ). Expressed mathematically, this is:

$$R = \pm K \sin \theta \quad (1)$$

where:

± = indicates the direction of movement: plus away from the groove in which the master guide wheel is located and minus toward the groove.

5.1.1 To compute the deflection of the casing from the vertical at any measurement point, use the following (see Fig. 3):

$$d = L \sin \theta \quad (2)$$

where:

L = distance between measuring wheels, and
d = deflection.

5.1.1.1 The algebraic difference in readings ($R_1 - R_3$) in opposite grooves (180° apart) can be used to minimize errors contributed by casing and instrument irregularities (Note 1):

$$\text{Difference} = (R_1 - R_3) = \pm 2K \sin \theta \quad (3)$$

Solving for sin θ:

$$\sin \theta = \frac{\text{Difference}}{2K}$$

and substituting into Eq 2 we have:

$$d = \frac{L}{2K} \text{Difference} \quad (4)$$