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Indian Standard

MONITORING OF ROCK MOVEMENTS USING PROBE INCLINOMETER — GUIDELINES

ICS 07.060
AMENDMENT NO. 1 DECEMBER 2006
TO
IS 14395 : 1996 MONITORING OF ROCK MOVEMENTS USING PROBE INCLINOMETER — GUIDELINES

(Page 1, clause 2.1, line 9) — Substitute 'reusable' for 'usable'.

(Page 1, clause 2.2.2) — Substitute 'Ea' for 'E'.

(Page 1, clause 2.2.3, last line) — Substitute 'radiotelemetry' for 'radioelemetry'.

(Page 2, Fig. 1) — Substitute the following for the existing figure:

![Diagram of Probe Inclinometer]

**Fig. 1 Probe Inclinometer**
Amend No. 1 to IS 14395 : 1996

[Page 2, clause 3.2(h), line 1] – Substitute ‘robust’ for ‘rebus’.


(CED 48)
FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

Monitoring of rock movements is done to ensure safety during construction and operation. It helps in receiving a fore-warning of the impending failure and taking corrective measures. One of the methods to monitor the movement of rock is by using inclinometer.

In the formulation of this standard, assistance has been derived from the suggested method of International Society of Rock Mechanics.

Technical Committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 "Rules for rounding off numerical values (revised)". The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
Indian Standard
MONITORING OF ROCK MOVEMENTS
USING PROBE INCLINOMETER —
GUIDELINES

1 SCOPE

1.1 This standard covers one of the methods of monitoring rock movements where a borehole is either available or drilled and a probe inclinometer is used.

2 MONITORING SYSTEMS

2.1 The instrumentation system for monitoring rock movements using probe inclinometers shall generally have three components. A probe which responds to the rock movements, a transmitting system which may use rods, electrical cables, radiotelemetry devices, etc, for transmitting the sensor output to the readout location. A readout/recording unit such as dial gauges, digital display, magnetic tape recorder etc, which converts the data in usable form for the user.

2.2 Probes Used for Monitoring Rock Movements

2.2.1 Probes with Electric Resistance Strain Gauges

These operate on the principle that the resistance of a wire changes proportionately with strain. In strain gauge systems, strain gauges made from thin wire or foil, are bonded to a cantilever spring. Changes in the inclination of the probe are accompanied by changes in the strains and resistances of the strain gauges which are read using a Wheatstone bridge circuit.

2.2.2 Probes with Vibrating Wire Sensors

These are based on the fact that the natural frequency of vibration of a stretched wire depends on the tension in the wire. Vibrating wire transducer shall contain two electromagnets, one of these is the exciter and the other acts as a pick up. When the wire is forced to oscillate, an alternating current is induced in the second electromagnet which has the same frequency as the natural frequency of the vibration of the gauge wire. The signal when amplified provides a measurable quantity in terms of frequency. Once this frequency is known, any physical quantity can be calculated using calibration schemes. The strain in the gauge and its frequency of vibration are expressed as:

\[ f = \frac{(LC)^{\frac{1}{2}}}{2\pi} \]

where \( L \) is the self-inductance and \( C \) the capacitance of the solenoids. A relative displacement, \( d \), of the inner and outer solenoids produces a change in the measured resonant frequency, \( f \), such that

\[ d = K \left( 1 - \left(\frac{f_a^2}{f^2}\right)^n \right) \]

where \( f_a \) is the calibrated frequency for the null position and \( K \) is a constant. Several of the bore hole extensometers and inclinometers are based on this principle. These instruments may be read remotely using radiotelemetry.

3 PRINCIPLES OF OPERATION OF PROBE INCLINOMETERS

3.1 The instrument measures ground movements only in directions perpendicular to the borehole axis. Most of the available instruments are designed to operate in near vertical boreholes, in which case only horizontal movements can be recorded.

The probe inclinometer gives a complete and detailed profile of displacement, along the borehole, in the lateral direction.

However such inclinometer system is not suitable for continuous or remote reading.

3.2 Apparatus

a) A probe inclinometer shall consist of a probe or torpedo fitted with guide wheels and containing a gravity-operated tilt sensor which generates an electrical signal and is connected by an electrical cable to a power source and readout box for recording the angle \( \theta \) between the probe axis and the vertical (Fig. 1). The probe shall operate in a guide tube grouted into a borehole (\( NX \) size), the probe being lowered in stages and the tilt measured at each stage. As shown in Fig. 1, measurements of tilt and probe depth shall be used to compute horizontal deviations of the guide tube from true vertical. Differences between successive sets of measurements shall indicate horizontal movement of the entire guide tube.

b) The guide tubing shape and dimensions shall be designed to suit the probe to be used. Typically the tubing shall be constructed of plastic or epoxy-resin coated aluminium with four orthogonal internal keyways to accept the
probe guide wheels. Plastic casing may be preferred for long life, as it is protected from corrosion. The guide tube shall be assembled for individual lengths of tubing up to 3 m long with couplings which are butt-jointed or telescopic. Design of the couplings, their telescopic travel and method of fixing may be such that it allows the installed guide tube to readily compress or extend axially by an amount equal to the ground compression or extension. Couplings shall be made water-tight to prevent grout from entering the guide tube. Telescopic couplings may be used where significant axial movements are anticipated even though non-telescopic butt-casings provide better tracking and easier depth reading control.

The assembled guide tube should be sufficiently flexible to follow changes in borehole curvature caused by ground movements. In use, the tubing should not substantially affect the magnitude of ground movements, nor should distortion or buckling of the tube occur to an extent that impedes free passage of the probe.

c) Keyways in the assembled guide tube shall be such that they allow free passage of the inclinometer probe. The keyways ideally should be straight so that the probe does not rotate about its axis by more than $1^\circ$ in any 3 m of travel in the installed tube, and preferably by not more than $5^\circ$ in the complete assembled length.

d) Grouting material shall be placed to completely fill the annular space between the guide tube and the borehole, the set grout generally having a rigidity comparable with that of the rock in which the tube is installed.

e) The probe shall comprise of a cylindrical housing with spring-loaded wheel assemblies set typically 1/2 m or 1 m apart to locate it in the guide tube keyways. The housing shall contain a tilt sensor to measure the angle between the probe axis and the vertical, this angle being measured in the plane of the guide wheels. The sensing device is connected by an electric cable to a compatible readout box.

f) The measuring range, sensitivity and accuracy of the probe with its readout box shall be specified according to the specific requirements of the project. Reproducibility of the equipment when operating under site conditions in general, shall be kept equal to or better than ±0.01°.

g) The equipment shall be designed to ensure that the specified accuracy is maintained irrespective of normal mechanical handling, water pressures and corrosive environments encountered in use.

h) The cable shall be robust and functional without leakage or excessive stretching under the tension that results from friction and from the weight of cable and probe. The cable shall be permanently and clearly graduated to enable measurement of probe position with an accuracy better than 5 mm or ±0.05 percent of the depth at which the probe is to operate, whichever is greater.

j) Calibrating device enables frequent checking of the equipment. Such calibrating devices allows the probe to be set in a section of guide tube identical to that in which the probe is to operate; the inclination of the guide tube being adjustable from vertical to the maximum operating angle of the probe, with at least one intermediate setting either side of vertical. The calibrator should have an independent angle measuring device of accuracy better than 0.01°.

4 PROCEDURE

4.1 Preparatory Investigations

Inclinometer borehole locations and depths shall be selected on the basis of a study of the geotechnical features of the site, taking into consideration the directions and magnitudes of anticipated ground movements.
4.2 Installations

a) Boreholes shall be drilled to the full depth of measurement at required locations. If steel casing is used to maintain the hole open, it shall be fully withdrawn in the course of installing the guide tube.

b) Prior to installation of guide tubing the ground conditions shall be established by inspection of the core and/or the borehole. A comprehensive geotechnical borehole log shall be compiled with particular attention being given to zones of potential movement.

c) The guide tube lengths shall be assembled, each correctly oriented and inserted in the borehole. The base tube shall be fitted with a watertight cap. If vertical movements are anticipated all couplings should be free to telescope and should be sealed to prevent ingress of grout. If the borehole is full of water or drilling mud, or if it is pre-filled with grout, the guide tubing may be filled with clean water to facilitate insertion. If the tubing is inserted in a dry hole, its weight should be carried by an external tie wire fixed to the lower end of the guide tube and banded to it at intervals.

d) After insertion is complete, the azimuth of the guide tube keyways should be recorded to an accuracy of $\pm 3^\circ$. The guide tube should then be clamped in position and if necessary checked for spiral with a spiral measuring probe.

e) The annular space between guide tube and borehole shall be grouted. In water-filled holes, a tremie pipe will be required to prevent mixing of water and grout and in deep boreholes such a pipe is mandatory. Disposable grout valves are available which permit grouting from inside the guide tube through the drill rod. After grouting, the interior of the guide tube should be flushed with clean water and may, in addition, require brushing. The water may be left in place or the tube may be pumped dry after the grout has set.

f) A protective lockable cap or cover should be installed over the exposed end of the guide tube to prevent entry of debris and discourage vandals. Positions and elevations of guide tube collars to be used as a reference for depth measurements should be noted and recorded to an accuracy of $\pm 5$ mm.

g) The probe should be checked at site both before and after each day’s readings. Instrument malfunction should be promptly investigated and corrected and a diary of calibrations and adjustments should be kept. Unnecessary adjustment must be avoided.

h) Several sets of initial readings shall be taken immediately after the grout has set. These readings shall be averaged to provide a baseline for all subsequent observations. Thereafter readings may be taken at intervals on the basis of site requirements.

i) The probe shall be inserted with its guide wheels in one pair of keyways and lowered to the bottom of the hole. A measuring traverse shall be made starting at the bottom comprising measurements at intervals along the complete length of guide tubing, with the probe held stationary at each measuring location while readings of the depth and inclinometer display shall be recorded. These shall be tabulated together with information on the date, time, location, direction and keyway identification. The measurement interval, in general, is kept equal to the spacing between probe guide wheels although readings may be taken at twice this interval in many cases with little loss of accuracy.

j) The probe shall be withdrawn, rotated through $180^\circ$ and re-inserted with its guide wheels in the same pair of keyways and lowered to the bottom of the hole. A second measuring traverse shall be completed as described in above. Measuring locations shall be kept identical to those for the first traverse, in which case the face error for pairs of corresponding readings is determined which should be relatively constant at every location. This provides an important field check on data reliability.

k) If required, two further measuring traverses shall be made, as above but with the probe guide wheels in the second pair of keyways.

5 DATA PROCESSING

a) All data should be processed as quickly as possible after taking readings.

b) The field data shall be scrutinized and obvious errors marked on the field data sheet. If corrections are made, these should be clearly noted.

c) Pairs of opposite-face readings shall be averaged to correct face error. The sign convention and details procedure used in reducing data varies so that manufacturers’ manuals should be scrutinized carefully. The direction of movement must be carefully checked and recorded.

d) Corrected readings shall be subtracted from initial readings at the same guide tube location to determine the incremental changes in angle or displacement.

e) These incremental changes in angle ($80^\circ$ degrees) may, if required, be converted into incremental displacements ($\Delta$, in mm) using the following formula:

$$\Delta = L \sin 80^\circ$$

(where $L$ in mm is the distance between successive readings).

f) Incremental angle or displacement changes shall be then summed, normally from the bottom of the guide tube, in order to construct a graphical plot of total displacement versus depth. It is often useful to plot incremental angular (displacement) changes with depth to indicate movement zones.
ANNEX A
(Foreword)

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(Continued on page 5)
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Amendments Issued Since Publication

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