IS 12955-2 (1990): Code of practice for in-siitu determination of rock mass deformability using flexible dilatometer, Part 2: Radial displacement [CED 48: Rock Mechanics]

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भारतीय मानक

नम्य विस्फारमापी का उपयोग करते हुए मौके पर शैल-संहति विरूप्यता ज्ञात करने की रीति संहिता

भाग 2 भिन्य विस्थापन

Indian Standard

IN-*SITU* DETERMINATION OF ROCK MASS DEFORMABILITY USING A FLEXIBLE DILATOMETER — CODE OF PRACTICE

PART 2 WITH RADIAL DISPLACEMENT

UDC 624·121·54 : 006·76

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FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards on 24 April 1990, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

Deformability of rock mass near exposed surface can be determined by many methods such as uniaxial jacking test, radial jacking test, flat test, etc. On the other hand borehole instruments like dilatometers can be used to produce a log of deformability variations with depth. In this they are superior to other methods which are designed only for near-surface application. Dilatometers are particularly valuable for the rapid index logging of drillholes in fragile, clayey or jointed/closely rocks that yield poor core recovery and inadequate specimens for laboratory testing. The deformability values obtained by dilatometer logging give a very useful record of variations in rock quality and useful comparison of relative deformabilities in adjacent rock strata.

The volume of rock stressed by a dilatometer is quite small, usually less than one third of a cubic metre and often too small for direct application of the results to design problems. Correlation of the dilatometer modulus with that obtained, for example, by plate jacking radial jacking, or flat jack methods allows an extrapolation of the dilatometer test results to the large scale. Adjustments are also needed to take into account the fact that a dilatometer test carried out in a vertical hole gives information on horizontal deformability, whereas it is vertical deformability that is often more relevant, for example to foundations.

Both the types of dilatometers referred to in this standard are 'flexible' in that they apply a uniformly distributed pressure to the drillhole wall through a flexible membrane, and in this, they differ from 'rigid' dilatometers such as the goodman jack which has semi-cylindrical loading platens or steel, and, therefore, directional pressure application.

The two methods given here relate to two types of 'flexible' dilatometers. The first covered in Part 1 measures the drillhole volume change from which radial displacements must be calculated, whereas the second covered in Part 2 measures the radial displacements directly using displacement transducers. Only the direct measuring type can be used to determine anisotropy of deformability as a function of radial direction within the drillhole, volume change types give an average value for the deformability modulus.

The present standard is limited to describing the measurement of rock mass deformability, which is the principal use of the dilatometer.

Indian Standard

IN-SITU DETERMINATION OF ROCK MASS DEFORMABILITY USING A FLEXIBLE DILATOMETER — CODE OF PRACTICE

PART 2 WITH RADIAL DISPLACEMENT

1 SCOPE

1.1 This standard (Part 2) covers the method for determination of deformation modulus of rock *in-situ* using an expanding, probe (dilatometer) to exert pressure on the walls of a drillhole. The resulting hole expansion (dilation) is measured directly by a displacement transducer in the probe. Deformability characteristics of the rock mass at the dilatometer location may be calculated from the relation between pressure dilation. Anisotropy of deformability in the plane perpendicular to the drillhole may also be determined.

2 REFERENCE

2.1 The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 LOCATION OF TEST SITE

3.1 Drillhole locations and depths are to be selected taking into account the anticipated rock quality variations and depths of weathering, and the requirements of the designs of which the test data are needed.

3.2 Within each drillhole, the tests may be spaced either at equal intervals or at specified locations in pre-selected geological formations or beds. Generally, a log of deformability should be taken at regular interval along the length of the test hole pertinent to design. For example a 1, 2 or 5 m test interval may be specified depending on test hole lengths and required resolution.

4 PREPARATION OF TEST SITE

4.1 Test holes are to be drilled with the utmost care to preserve their stability, bearing in mind that rock fragments inadvertently wedged between the probe and the drillhole wall can trap the dilatometers permanently. The hole diameter is to be 0·5-3·0 mm larger than the deflated diameter of the probe.

4.2 For checking of the drillhole use of a TV camera may be considered to avoid damage to the flexible membrane that might be caused by open fissures or voids. When the drillhole requires support, this may be achieved by casing down to the uppermost test section and/or by cementing.

4.3 Drill cores are to be fully logged to record core recovery, fracture frequency, rock characteristics, weathering and structural features such as schistosity, foliation, bedding and joints. Rock cores are to be available on site for inspection by the testing crew, if necessary.

5 TEST EQUIPMENT

5.1 Equipment for drilling and preparing the test hole.

5.1.1 A drill or boring machine to produce a test hole of the required diameter to the required depth of investigation.

5.1.2 Casing as necessary to support the wall of the hole outside its test sections.

5.1.3 Equipment and materials for grouting and redrilling the test sections within the hole (*see* **4.2**).

5.1.4 A diameter gauge (for example, a cylinder of the same size as the probe) to check that the hole is clear for insertion of the dilatometer.

5.2 Calibration Equipment

5.2.1 A dummy probe of known elastic properties with internal diameter equal to that of the test hole and with length similar to the active length of the probe.

5.2.2 A micrometer gauge to measure the outside diameter of the probe, with an accuracy of +·0·02 mm or better.

5.3 The Dilatometer Probe (Fig. 1)

5.3.1 A dilatometer probe, which includes a high pressure flexible membrane mounted on a core, such that the membrane can be inflated to press against the drillhole wall. The membrane has to be strong enough to avoid damage when inserted into and withdrawn from the drillhole, yet flexible enough to transmit not less than 90 percent of the applied hydraulic pressure. Typical dilatometer probes have a diameter of 76 to 116 mm and effective lengths of 5-15 times their diameter.

5.3.2 A means of inserting, raising and lowering the probe in the hole and of measuring its position to within + 5 cm and its orientation to ± 5 degree. Drill rods, special installing rods or cables may be used.

CONTACT HEAD — TRANSDUCER

RELIEF VALVE — STEEL BODY — RUBBER JACKET

765
1050
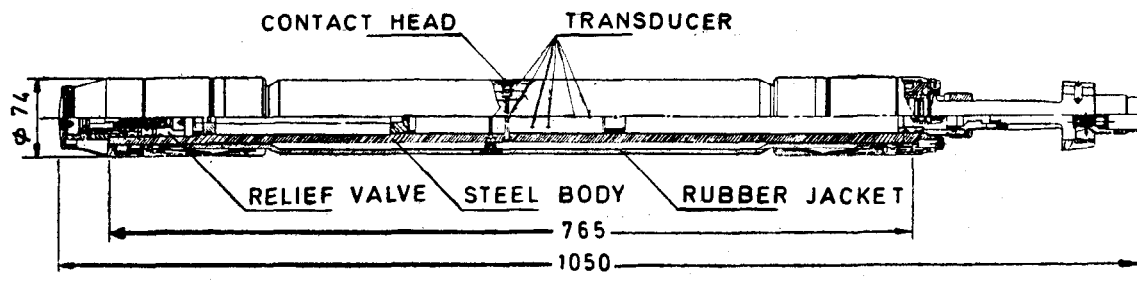
All dimensions in millimetres.
FIG. 1 LNEC-TYPE DILATOMETER

5.4 A Hydraulic System to Pressurize the Probe

5.4.1 A pump and tubing system capable of filling, inflating and deflating the probe and of applying and maintaining the required range of pressures.

5.4.2 The use of electrically operated pump with a pressure controller to maintain loads or apply a constant loading rate, may be preferred.

5.4.3 Testing in a large drillhole using a large diameter probe may require the use of two pumps, or a two speed pump with one pumping rate for filling the system and applying initial pressure, and another for pressurization.

5.5 Measuring Systems

5.5.1 One or more displacement measuring systems to determining drillhole diameter with an accuracy of $+ 0.02$ mm or better. For example, three electrical displacement transducers of LVDT (linear variable differential transformer) type may be mounted to measure along diameters inclined at 120 degrees to each other. The transducers are connected by electrical cables to a readout unit at surface.

5.5.2 A pressure measuring system such as Bourdon gauge or an electric pressure transducer, with range as required and with reading sensitivity better than $+ 2$ percent of the range to be employed in any one test.

NOTE — For measurements in hard rocks a pressure range of at least 20 MPa is recommended. Pressurizing fluids that have been used include glycerin, ethylene glycol, water or hydraulic oil.

6 TEST PROCEDURES

6.1 Calibration

6.1.1 The complete dilatometer equipment is to be thoroughly checked and calibrated before each test series, also at least weekly during a testing programme and after major repairs such as membrane replacement.

6.1.2 With the probe inserted in the calibration cylinder, the full test pressure is to be applied and a check made for pressure maintenance and leakage.

6.1.3 Pressure is then to be released and increased incrementally through the range to be used in actual testing, taking at least five readings of pressure (MPa) and corresponding dilation. If the cell contains more than one displacement transducer, the readings are to be compared and then averaged, a pressure versus average dilation curve is to be plotted and its slope mm (MPa per mm) compared with theoretical cylinder expansion obtained from elastic theory 2.

6.1.4 The probe is to be inflated in air (without confinement) to determine the membrane rigidity correction factor m (MPa/mm) obtained as the slope of the unconfined pressure dilation curve.

6.1.5 The displacement measuring system should also be independently checked using a micrometer, preferably one spanning directly between the measuring pads of the probe. Within the measurement range, the overall sensitivity of the equipment should be constant, for example, one dial division of the readout voltmeter per millimeter of dilation.

6.2 Testing

6.2.1 Having checked clearance of the hole using the diameter gauge, the probe is to be inserted and lowered or raised to the required test location. This location is to be measured with an accuracy of $+ 5$ cm and recorded.

6.2.2 The probe is to be expanded under a pressure just enough to ensure permanent contact with no sliding. This seating pressure is to be the minimum pressure throughout the test.

6.2.3 Pressure is to be increased in not less than five approximately equal increments to the maximum value, which is to be as high as possible but not greater than the safe operating pressure of the test equipment, taking into consideration the smoothness and diameter of the drillhole at the test depth.

6.2.4 Each pressure increment is to be maintained constant while taking readings of pressure (MPa) and corresponding hole dilation (mm). If the probe contains more than one displacement transducer, individual diameter readings are to be

recorded in order to compute modulus values as a function of direction. Dilation (if any) is to be recorded versus time to give an indication of whether the rock behaviour is time-dependent. Alternatively, the same can be achieved by maintaining the diameter of the probe constant and recording the drop in pressure with time.

6.2.5 At the maximum test pressure, the applied pressure is to be maintained constant during at least 10 minutes, longer if specified. Readings of dilation versus time at constant pressure are again to be tabulated to determine creep rates.

6.2.6 Dilation and pressure readings may then be taken during unloading if specified. Three cycles of loading and unloading are required in most applications.

6.2.7 During the test cycling, a pressure-dilation curve is to be plotted such as shown in Fig. 2.

6.2.8 Pressure is released, if the probe has just one displacement measuring direction, it may then be rotated at the same depth in the hole, and the test repeated to measure deformability in another direction. The probe is then relocated for the next test.

7 ANALYSIS OF THE TEST DATA

7.1 Calculation of Calibration Constants

7.1.1 The shear modulus G_c of a calibration cylinder material having Young's Modulus E_c and Poisson's ratio Υ_c is given by:

$$G_c = \frac{E_c}{2 (1 + \Upsilon_c)} \quad (MPa)$$

7.2 Calculation of Deformability Parameters of Rock

7.2.1 For any segment of the pressure-displacement diagram (see Fig. 2 and 3) and in rock with widely spaced joints (see **7.2.2** below), and corresponding secant dilatometric modulus, E_d may be calculated as follows:

$$E_d = (1 + \gamma_R) \frac{D \triangle P_1}{\triangle D} \quad (MPa)$$

where

$\triangle P_1$ = pressure increment within the considered segment (MPa),

$\triangle D$ = corresponding average change in drillhole diameter D (m), and

γ_R = Poisson's ratio of the rock mass.

7.2.2 If the test is performed in cracked rock, and if P_1 exceeds about twice the average ground pressure P_0 around the drill-hole, all existing radial cracks will open and the equation of **7.2.1** is to be replaced by:

$$E_d = \frac{D P_1}{\triangle D} \left(1 + \gamma_R \right) \left[(1 - \gamma_R) \right.$$
$$\left. + l_n \left(\frac{P_1}{2 P_0} \right) + 1 \right] (MPa)$$

where

P_1 = applied pressure (MPa), and

$\triangle D$ = average increase of drillhole diameter (m) when pressure increases from zero to P_1

NOTE — The equations of **7.2.1** and **7.2.2** are strictly valid only for a linear elastic, homogeneous and isotropic rock mass.

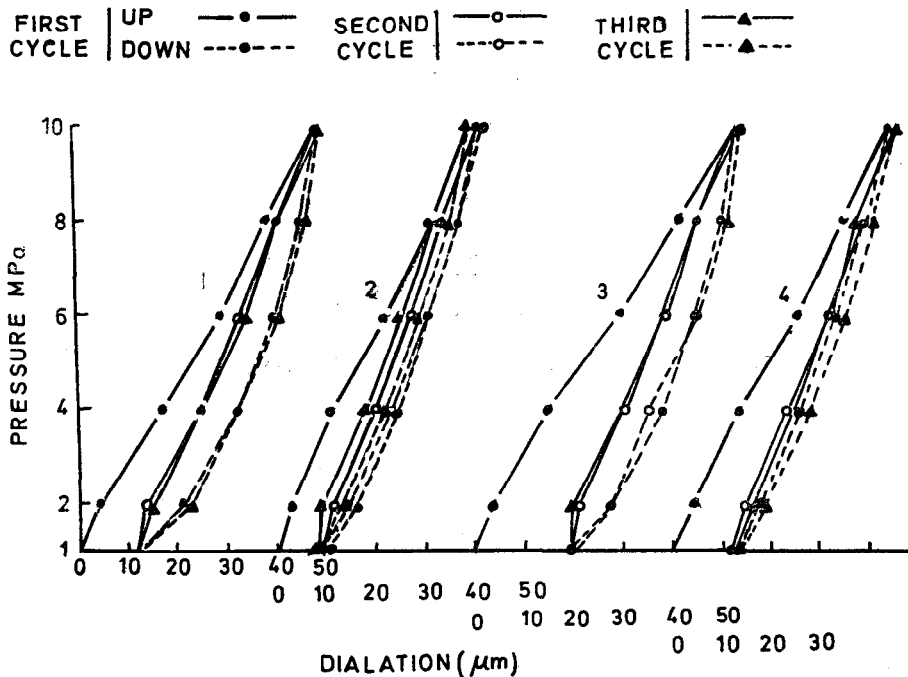FIRST CYCLE | UP ——•—— DOWN ---•--- SECOND CYCLE ——○—— ---○--- THIRD CYCLE ——▲—— ---▲---

FIG. 2 PRESSURE-DILATION CURVES, SHOWING SEPARATE CURVES FOR EACH OF FOUR DILATION-MEASURING TRANSDUCERS MOUNTED IN THE SAME PROBE

SCALE FOR DILATION $(\times 10^{-2} mm)$

0   20   40

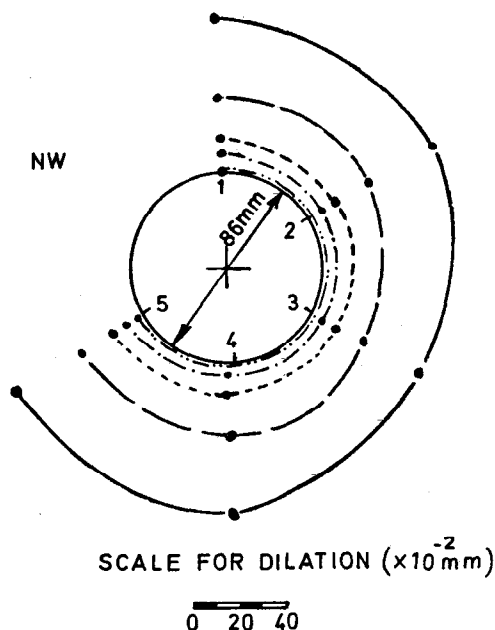FIG. 3   DILATIONS OF DRILLHOLE WALL,
MEASURED BY DILATOMETER WITH THREE
DISPLACEMENTS TRANSDUCERS, AT PRESSURES OF
1, 2, 5, 10, 20 AND 40 MPa

7.2.3 When the cell contains several diametral displacement transducers or when a single transducer cell has been rotated to measure anisotropy of deformability, the measured dilations for several directions of measurement are to be plotted as shown in Fig. 3. Deformability values are then to be calculated for each direction of measurement.

7.2.4 From the pressure-dilation diagram, both short-term and time dependent response of the rock mass can be determined.

8 REPORTING OF RESULTS

8.1 The following are to be reported for the site as a whole:

a) Details of drilling including drilling agency, method and equipment used.

b) A map of drillhole locations and a tabulation of hole lengths, diameters, inclinations and directions.

c) Geotechnical logs of the drill core, showing locations of cased and cemented sections, if any, groundwater levels, rock types and characteristics, locations of test sections.

d) Characteristics of all discontinuities within each test section and 0·5 m above and below [see IS 11315 (Parts 1 to 11)].

e) Details of the method and equipment for calibration and testing, stating departures from the procedures given in this standard.

f) Full results of calibration.

8.2 The following are to be reported for each test:

a) Tabulated test readings, including both raw and corrected values with depths and directions of measurement and graphs as in Fig. 2.

b) Derived values of deformability parameters, together with details of methods land assumptions used in their derivation. Deformability parameters should be tabulated and shown graphically as a function of applied pressure.

c) Logs of deformability variation as a function of depth (or distance from the drillhole collar in case of a non-vertical hole).

d) Graphs in the plane perpendicular to the drillhole, showing anisotropy of the measured dilations and deformability values.

ANNEX   A

(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	Title
11315 (Part 1) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 1 Orientation
11315 (Part 2) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 2 Spacing
11315 (Part 3) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 3 Persistence
11315 (Part 4) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 4 Roughness

IS No.	*Title*
11315 (Part 5) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 5 Wall strength
11315 (Part 6) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 6 Aperture
11315 (Part 7) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 7 Filling
11315 (Part 8) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 8 Seepage
11315 (Part 9) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 9 Number of sets
11315 (Part 10) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 10 Block size
11315 (Part 11) : 1985	Method for the quantitative description of discontinuities in rock mass: Part 11 Core recovery and rock quality

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected