IS 12955-1 (1990): Code of practice for in-situ determination of rock mass deformability using a flexible dilatometer, Part 1: volume change [CED 48: Rock Mechanics]

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(Reaffirmed 2001)

भारतीय मानक

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

भाग 1 आयतन परिवर्तन संहिता

Indian Standard

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

PART 1 WITH VOLUME CHANGE

UDC 624·121·54

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Price Group 3

Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard 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 jack test, etc. On the other hand borehole instruments like dilatometer 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 closely jointed 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 a 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 of steel and therefore, directional pressure application.

The two methods given here relate to two type 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

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

PART 1 WITH VOLUME CHANGE

1 SCOPE

1.1 This standard 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 diametral hole expansion (dilation) is determined from measurements of the volumetric expansion of the probe. Deformability characteristics of the rock mass at the dilatometer location may be calculated from the relation between pressure and dilation.

2 REFERENCE

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

3. LOCATION OF TEST SITE

3.1 Drill hole locations and depth shall be selected taking into account the anticipated rock quality variations and depths of weathering, and the requirements of the designs of structures for which the test data are to be used.

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 The test holes shall 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 dilatometer permanently. The hole diameter shall 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 require support, this may be achieved by casing down to the uppermost test section and/or by cementing.

4.3 Drill cores shall be fully logged to record recovery and the characteristics of the rock and jointing. Rock cores shall be available on site for inspection by the testing crew, if required.

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. A rotary diamond coring to give a smooth-walled drillhole at the section machine shall be used.

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 (when required, *see* **3.2**).

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

5.2 Calibration Equipment

One or more calibration cylinders 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.

5.3 The Dilatometer Probe

5.3.1 A dilatometer probe or cell (*see* Fig. 1 and 2) which includes a high pressure flexible membrane mounted on a core, such that the membrane may be inflated to press against the drillhole wall. The membrane must be strong enough not to be damaged when inserted into and withdrawn from the drillhole, yet flexible enough to transmit not less than 90 percent of the designed hydraulic pressure, when applied.

5.3.2 A means of inserting, raising and lowering the probe in the hole and of measuring its position to within ±5 cm such as drill rods, special installing rods and cables.

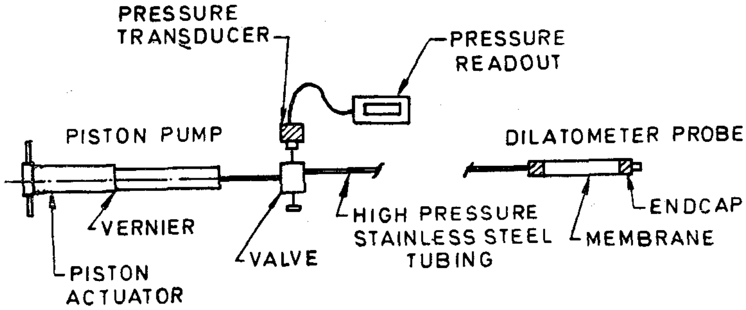

FIG. 1 COMPONENTS AND TYPICAL FLEXIBLE DILATOMETER SYSTEM

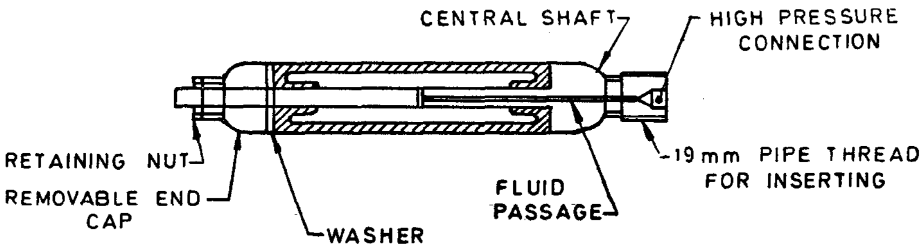

FIG. 2 CROSS-SECTION OF TYPICAL FLEXIBLE DILATOMETER SYSTEM

5.4 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 A hand-operated screw pump (or 'pressure generator') is usually employed because it serves the two-fold purpose of applying pressure and measuring volume displacements of the fluid. Piston movement is actuated by turning the wheel of the pump.

5.4.3 If volume measurements are made outside the drillhole, the hydraulic system must be of rigid construction to minimize errors in determining dilation and to facilitate cyclic loading and stress relaxation testing. Alternatively, the expansion of hydraulic lines is immaterial and can be ignored if volumetric expansion is monitored directly within the probe.

5.4.4 Testing in large drillholes using a large diameter probe may call for the use of two pumps, a high displacement one for filling the system and applying initial pressure, in addition to the screw pump for pressurization.

5.5 Measuring Systems

5.5.1 A volume measuring system, accurate to ± 1 percent of the cell volume, to determine the amount of hydraulic fluid injected into or extracted from the cell. Volume is usually measured as the number of turns or part turns of the screw pump.

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

5.5.2 A pressure measuring system such as a Bourdon gauge or electrical transducer, with range as required and with reading sensitivity better than ±2 percent of the range employed in the test.

6 TEST PROCEDURE

6.1 Calibration

6.1.1 The purpose of calibration is to determine the system stiffness M, the value of which is required to allow calculation of the volume change of the test section from the measured volume change of the probe and the hydraulic system combined.

6.1.2 The complete dilatometer equipment shall be thoroughly checked and calibrated before each test series, also at least weekly during a test programme and after major repairs such as membrane replacement. The temperature at the time of calibration shall be recorded and the calibration repeated if this changes by more than 5°C from that of the borehole.

6.1.3 The probe, pump and hydraulic system to be used in the field shall be connected and filled with hydraulic fluid and checked for leaks. Any entrapped air shall be removed by thorough bleeding.

6.1.4 With the probe in the calibration cylinder, pressure shall be increased incrementally through the range to be used in testing, taking at least five readings of pressure (MPa) and corresponding volume (pump turns). [A pressure-volume curve shall be plotted and its slope M_m (MPa per turn), the overall stiffness of the system plus calibration cylinder measured therefrom.] M_s is to be calculated from M_m as described in **6.1.3**.

6.1.5 The probe shall be inflated in air (without confinement) to determine the membrane rigidity correction factor m (MPa per turn), obtained as the slope of the unconfined pressure dilation curve.

6.2 Testing

6.2.1 Having checked clearance of the hole using the dummy probe, the probe shall be inserted and lowered or raised to the required test location. The location shall be measured with an accuracy of ±5 cm and recorded.

6.2.2 The probe shall be expanded under a pressure just enough to ensure permanent contact with no sliding. At no stage of testing, the pressure on the borehole walls shall be allowed to go below the seating pressure.

6.2.3 Pressure shall be increased in not less than five approximately equal increments to the maximum value, which shall be as high as required from design consideration (i. e. upto 1·5 times the design pressure) but not greater than the safe operating pressure of the test equipment, taking into consideration the smoothness and diameter of drillhole at the test depth. The rate of loading shall be maintained constant as far as possible.

6.2.4 At each increment the pressure is to be maintained constant while taking readings of pressure (MPa) and corresponding volume (pump turns). Dilation (if any) is to be recorded versus time to give an indication whether the rock behaviour is time dependent. Alternatively, the same may be achieved by maintaining the volume of the probe constant (without pumping) 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 or 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 A pressure-volume curve is to be plotted and its slope M_T (MPa per turn), the overall stiffness of system plus rock, determined (*see* Fig. 3).

6.2.8 Pressure is then to be released and the probe relocated for the next test.

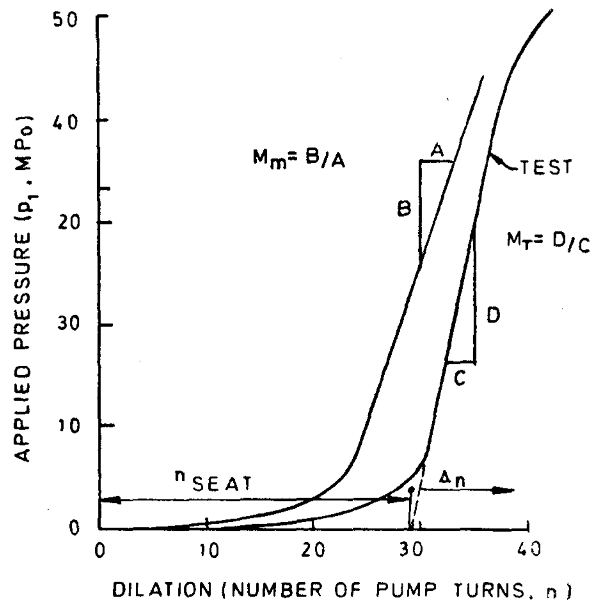

FIG. 3 PRESSURE-DILATION GRAPHS FROM A CSM DILATOMETER TEST

7 ANALYSIS OF THE TEST DATA

7.1 Calculation of Calibration Constant

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:

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

7.1.2 The stiffness M_c of the calibration cylinder is calculated as:

$$M_c = \frac{\alpha G_c}{\pi L a^2 \left[\frac{1 + B_c (1 - 2 \Upsilon_c)}{1 - B_c} \right]} \text{ (MPa per turn)}$$

where

α = pump constant (fluid volume displaced per turn of pump wheel),

L = length of cell membrane (m),

a = the inside radius and b the outside radius of the calibration cylinder (in metres), and

B_c = $(a/b)^2$.

7.1.3 The stiffness M_s of the hydraulic system is calculated as:

$$M_s = \frac{M_c M_m}{M_c - M_m} \quad \text{(MPa per turn)}$$

where M_m is the stiffness of the system plus calibration cylinder, measured as described in **6.1.4**.

7.2 Corrections for Pressure and Volume Losses

7.2.1 *Pressure Losses*

Observed pressure (those read on the pressure gauge or transducer) are only equal to those acting on the rock if the membrane is very flexible or the dilations are very small. Usually the observed pressure will require correction for membrane rigidity as follows:

$$Pi_{corr} = P_i - nm \quad \text{(MPa)}$$

where Pi_{corr} is the corrected pressure, n is the total number of turns needed to attain P_i and m (MPa/turn) is the membrane rigidity correction factor (*see* **6.1.5**).

7.2.2 *Volume Losses*

These occur as a result of probe seating and inflation of the loading system. Using measurements defined in Fig. 3, the net corrected number of turns Δn_{corr} is calculated from:

$$\Delta n_{corr} = n - n_{seat} - Pi/M_s \quad \text{(turns)}$$

7.3 Calculation of Linear Elastic Parameters of Rock

7.3.1 The stiffness M_R for the test section in rock is calculated as:

$$M_R = \frac{M_s M_T}{M_s - M_T} \quad \text{(MPa per turn)}$$

7.3.2 The dilatometric shear modulus G_d for a drillhole test section is calculated as:

$$G_d = M_R \frac{\pi L a^2}{\alpha} \quad \text{(MPa)}$$

where L and a are the length and diameter of drillhole test section and α is the pump constant (*see* **7.1.2**).

7.3.3 The dilatometric shear modulus G_d for dilatometer test in a rock cylinder is calculated as:

$$G_d = M_R \frac{\pi L a^2}{\alpha} \left[\frac{1 + B_c (1 - 2 \Upsilon_R)}{1 - B_c} \right] \quad \text{(MPa)}$$

with notation as before, but with B referring to the tested rock cylinder.

7.3.4 The dilatometric modulus of elasticity E_d for a test in either a drillhole or in a rock cylinder may then be obtained from:

$$E_d = 2 (1 + \Upsilon_R) G_d \quad \text{(MPa)}$$

where Υ_R the Poisson's Ratio for the rock is either known or estimated.

7.4 Calculations for Non-Linear Behaviour

7.4.1 If the drillhole is located in closely jointed rock, the measured pressure-volume relation may become non-linear when the applied pressure exceeds about twice the average ground stress. In that case and assuming zero tensile strength for the rock mass, G_d can be calculated from:

$$G_d = Pi_{corr} \frac{\pi L a^2}{\alpha \, \Delta n_{corr}} \left[(1 - \Upsilon_R) \, l_n \frac{(Pi_{corr})}{2 P_o} + 1 \right] \quad \text{(MPa)}$$

where Pi_{corr} and Δn_{corr} are the corrected values for applied pressure and number of turns (**6.2**) and P_o is the average ground stress around the drillhole (MPa), to be estimated or measured independently.

7.4.2 Alternatively one can obtain a pressure versus dilation curve by plotting Pi_{corr} on the ordinate and V_m on the abscissa, where

$$V_m = \alpha (n - P_i/M_s) \quad (m^3)$$

The curve can be used subsequently in the same manner as in a Monard pressuremeter test.

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 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 (Part 1 to 11) : 1985].

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 value with depths of measurements and graphs.

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

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

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
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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