SWEDISH GEOTECHNICAL SOCIETY

Recommended Standard for Dilatometer Tests

SGF Report 1:95E

SVENSKA GEOTEKNISKA FÖRENINGEN
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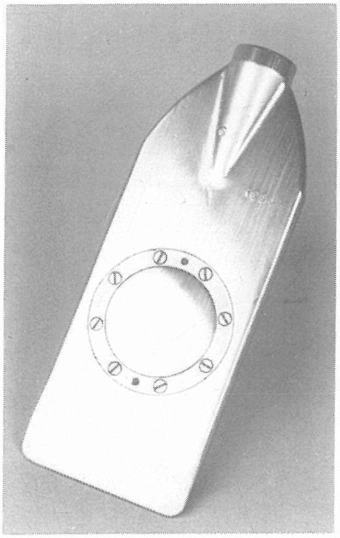

The Dilatometer consists of a steel plate, whose lower end tapers with a slight convexity to a straight edge. In the middle of one of the plate's flat sides is a circular steel membrane. This can be expanded by applying of a gas pressure to its interior via a pressure tube from the ground surface.

The dilatometer is pushed vertically into the ground at a constant rate of penetration of 20 mm/s. At the test levels, normally every 0.2 m, the penetration is stopped and the membrane is expanded by increasing the gas pressure. The pressures required for the membrane to start moving outwards from the plate, p_0, and to be expanded by 1.1 mm, p_1, respectively are read off with a manometer.

The main purpose of the test is to obtain a picture of the stratification and variations in the properties of the soil. The use of the method is limited to soils with grain sizes up to the gravel fraction and in which the dilatometer can be pushed down.

2. Present Standards and Recommendations

In Sweden, there is no previous recommended standard for dilatometer tests. An American standard for the test has been elaborated by ASTM in 1986.

Manuals for performance, reporting and interpretation of the test, which are not standards, have been published by Schmertmann & Crapps Inc. Gainesville Fla 1988, the Swedish Geotechnical Institute Linköping 1989 and the Norwegian Public Roads Administration, Norwegian Road Research Laboratory Oslo 1992, among others.

3. Definitions

From the dilatometer test, two measures read off on the manometer in the regulation unit are obtained. To enable interpretation and evaluation of the tests, a number of auxiliary parameters are required.

In situ pore pressure u_0

The in situ pore pressure u_0 corresponds to the existing equalized pore pressure at the test level in the ground. The pore pressure profile in the ground has to be known when the dilatometer tests are evaluated.

Effective overburden pressure σ'_{v0}

The effective overburden pressure σ'_{v0} is obtained from the density of the soil and the in situ pore pressure. If the density of the soil is not determined by sampling, an approximate value of the density can be estimated empirically from the results of the dilatometer test.

Zero Reading Z_M

Z_M is the value that is read off on the manometer when this is vented in such a way that the pressure corresponds to the atmospheric pressure.

Calibration Value ΔA

The calibration value ΔA is the inner excess pressure required for moving the unloaded membrane 0.05 mm out from the plate. Unloaded in this context means that only the atmospheric pressure acts on the outside of the membrane. In reality, ΔA is a negative pressure in relation to the atmospheric pressure (the membrane has to be sucked in against the plate or pressed in by an external pressure) but it is recorded as a positive value.

Calibration Value ΔB

The calibration value ΔB is the excess pressure required to press out the unloaded membrane 1.1 mm from the plate.

Reading A

Reading A is the value read off on the manometer when the membrane has expanded 0.05 mm during the test.

Reading B

Reading B is the value read off on the manometer when the membrane has expanded 1.10 mm during the test.

Contact pressure p_0

The contact pressure p_0 is the total horizontal pressure acting on the dilatometer after it has been installed at the test level and just before the membrane starts to lift off from the plate. The contact pressure p_0 is calculated as the pressure reading at 0.05 mm expansion of the membrane (ΔA) corrected for membrane stress (A) and zero offset of the manometer (Z_M) and adjusted to zero deformation by linear extrapolation using the expansion pressure at 1.10 mm deflection.

The following formula is used for calculating p_0

$$p_0 = 1.05(A - Z_M + \Delta A) - 0.05(B - Z_M - \Delta B)$$

Expansion pressure p_1

The expansion pressure p_1 is the excess pressure required to expand the membrane 1.10 mm during the test. p_1 is calculated from

$$p_1 = B - Z_m - \Delta B$$

Material Index I_D

The material index I_D is used for classification of the soil and is calculated from

$$I_D = (p_1 - p_0)/(p_0 - u_0)$$

Horizontal Stress Index K_D

The horizontal stress index K_D is a relative measure of the horizontal stress acting on the dilatometer after it has been installed at the test level. It is used for evaluation of properties of the soil.

$$K_D = (p_0 - u_0)/\sigma'_{v0}$$

Dilatometer Modulus E_D

The dilatometer modulus E_D is a measure of the stiffness of the soil. This modulus cannot be used directly for calculation of deformations but has first to be empirically converted into compression modulus M or modulus of elasticity E by using the other parameters. The dilatometer modulus is also used for classification of the soil in terms of stiffness.

$$E_D = 34.7(p_1 - p_0)$$

All parameters except I_D and K_D, which are dimensionless relations, shall be expressed in identical units throughout. Normally, kN/m^2 or bar is used.

4. Equipment

Dilatometer

The dilatometer consists of a steel plate with plane parallel sides and a circular steel membrane on one of the broad sides. The thickness of the plate shall be within the interval 13.5 to 15.0 mm. The diameter of the membrane shall be 60 mm. The length of the plate is normally 240 mm, but can vary somewhat between different models.

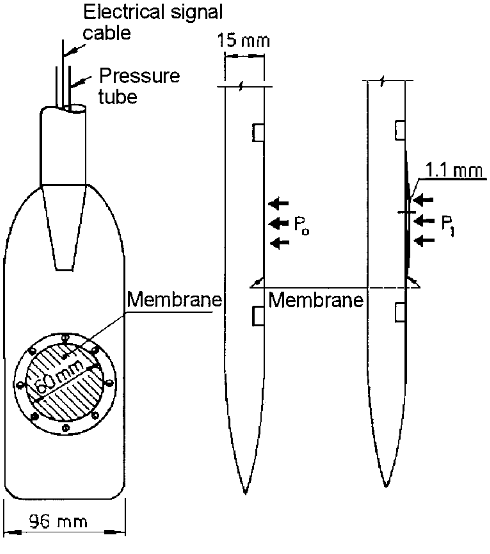

Figure 1. The dilatometer.

The lower part of the plate shall be tapered with a slight convexity ending in a straight edge with the same width as the plate. The outer corners of the edge may be rounded, however. For a new dilatometer, the apex angle shall be about 16 and the taper shall start about 50 mm up on the plate.

The width of the plate shall normally be 96 ± 1 mm. Exceptions from this, e.g. a smaller width of the plate to enable passage through protective casings with slightly smaller dimensions, can be accepted if comparative tests in the particular type of soil have shown that the results are compatible.

The dilatometer shall be straight. On its plane portion, the maximum acceptable deflection over a length of 150 mm is 0.5 mm.

The thickness of the membrane and its stiffness shall be adapted to the particular type of soil. For soft and medium stiff cohesive soils, thin membranes with calibration values ΔA and ΔB not exceeding 0.20 (20) and 0.35 (35) bar (kPa) respectively shall be used. For coarser and stiffer soils, thicker membranes with higher calibration values may be used.

Behind the membrane is a pressure chamber in which a distance measuring device is mounted. This shall close and break an electrical circuit when the centre of the membrane has moved 0.05 mm +0.02/-0.00 mm and 1.10 ± 0.03 mm respectively out from the plate.

Push rods

The dilatometer is connected to hollow rods for pushing down, usually via an adapter. When rod diameters larger than 36 mm are used, the adapter shall be tapered for a smooth transition to the larger diameter. The inner diameter shall be at least 16 mm both in rods and joints. Rods for the Swedish standard piston sampler St1, ϕ 36 mm sounding rods with hollow joints or similar rods can be used. Depending on the pushing equipment used, they shall be dimensioned for the maximum pushing force.

The joints shall have equal stiffness to the rods and the rods shall be straight. For the lowest 5 metres, the maximum deflection at the middle of a 1 m long rod may be 0.5 mm in relation to a straight line between the end points. The corresponding value for rods located further up is 1 mm. The same demand for straightness as for the rods also applies to the joints.

When the dilatometer has been attached to the rods, its edge shall coincide with the centre-line of the rods. The maximum allowable displacement is 1.5 mm. This is checked by laying the lower push rod with the attached dilatometer against a plane base with the edge parallel to the base. The perpendicular distance between base and edge is measured, whereupon the rod and dilatometer are rotated 180° and the distance is measured again. The difference between the two measurements may not be greater than 3 mm.

Pressure tube

The pressure tube between the dilatometer and the regulation unit shall be gastight. Minor leaks occurring in the field can temporarily be accepted. Leakages, which for a closed system result in pressure losses greater than 1 bar/min (100 kPa/min) are always unacceptable. When necessary, the pushing equipment shall be modified, e.g. by a slotted adapter, in order to prevent the tube being jammed or otherwise damaged.

Regulation equipment

For application of pressure a tank is used with compressed nitrogen or and pressure reducing valves. The regulation unit for the dilatometer is designed for a maximum pressure of 80 bars (8 MPa). The unit consists of a needle valve for flow regulated pressure application, a venting valve, a shut-off valve, connections for tubes to pressure tank and dilatometer, an audio-visual indicator for showing whether the electrical circuit in the dilatometer is open or closed, connections for the calibration equipment and manometers for pressure reading, Fig. 2.

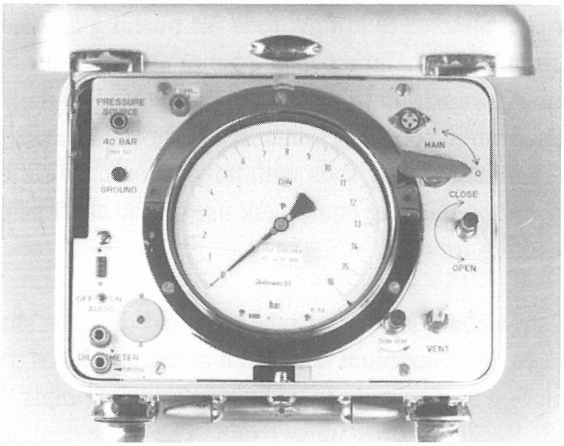

Figure 2. Regulation unit for dilatometer.

The manometers shall be equipped with transport protection. They shall either be interchangeable or connected in parallel and provided with overload protection. For tests in soft soils, manometers with a maximum measuring range of 16 bars (1.6 MPa) may be used. For stiffer soils, manometers with measuring ranges 0 - 40 bars (0-4 MPa) may be used and for very stiff soils 0-80 bars (0-8 MPa). The manometers shall have an accuracy of ± 0.5 % of the measuring range or better. They shall be calibrated regularly and the calibration may not be older than one year at the time of the test.

Calibration equipment for dilatometer membranes

The calibration equipment for the membrane consists of a hand pump, by which both suction and pressure can be applied manually, and a manometer with a measuring range of -1.0 bar to + 1.5 bars (-100 kPa to +150 kPa), Figure 3. The calibration manometer shall have an accuracy of 1.0 % of the measuring range or better.

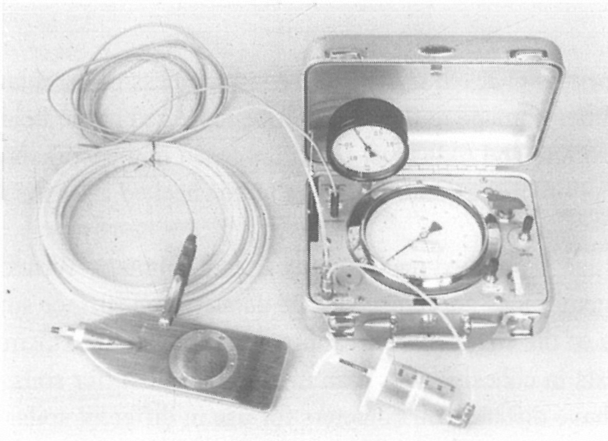

Figure 3. Calibration equipment for dilatometer membranes.

Pushing equipment

The pushing equipment shall permit vertical alignment and be able to push down the dilatometer and the rods at a constant rate of penetration of 20 ± 10 mm/s. It shall be ballasted or anchored in such a way that it does not move in relation to the ground during penetration and so that it can provide the required pushing force. Blows may be used only in exceptional cases in order to enable passing of stiffer layers at greater depth. The dilatometer is not designed for torsional forces and rotation must not be applied. Care shall also be taken at connection and disconnection of push rods in order to prevent torsional forces being transmitted to the dilatometer.

The dilatometer can be pushed down by a force of up to 100 kN. At forces over 50 kN and when driving with blows, the risk of damaging the equipment increases. A large part of the pushing force normally consists of rod friction. In order to reduce this, a local enlargement of the rod may be applied above the dilatometer, but not closer to the centre of the membrane than 0.5 m.

Depth recording

Depth recording is normally performed manually in relation to the ground surface at the test point, which is levelled. The error in the depth recording may not exceed 0.1 m.

5. Test procedure

Checks

- The equipment is checked regarding the straightness of the dilatometer and the rods. Minor damage to the edge can be remedied in the field by grinding. Bent dilatometers and rods must be straightened in the workshop. In this case, also the function of the dilatometer has to be checked after the repair.

- The membrane is checked regarding wear and tightness. Wrinkled and heavily scratched membranes are replaced. The demands on surface smoothness, straightness of the edge and low calibration values for the membrane are higher in tests in cohesive soils than in coarser and stiffer soils. It is therefore prudent to have different dilatometers for use in different soils. Otherwise, the suitability of the membrane for the particular soil has to be considered with respect to the measured calibration values and the specified demands on the membrane for different types of soil. As a result of this, the membrane may have to be replaced.

- The tightness of the pressure tube is checked.

- The checking of the tightness of the membrane and tube is performed by connecting the tube to the pressure unit and its outer end to the dilatometer or by plugging the tube. After application of pressure in the tube, the tightness can be checked by lowering the tube and dilatometer into water and checking that no gas bubbles appear. Alternatively, the valves and vents in the regulation unit can be closed and the tightness check can be performed by reading off the manometer, whereupon significant loss of pressure shall be observed within one minute. When checking an unprotected membrane, the pressure must be limited in order not to overexpand the membrane. At the same time, the tube shall be checked for the maximum pressure to be used in the tests. Simultaneous checking of tightness of both dilatometer and tube can be performed if the dilatometer is inserted into a casing which prevents the membrane from being expanded more than 1 mm.

Calibration

- The membrane is calibrated before and after each test series at the same test point. After replacing the membrane, the calibration is repeated several times until stable and repeatable calibration values are obtained. When moving from one test point to another without disassembling the equipment, the calibration after the tests at the first point can also be used as calibration before the tests at the new point.

- After removal of the transport protection, the zero reading of the manometer at atmospheric pressure is read off. Thereafter, the regulation unit may not be moved or inclined during the testing operation since this can affect the readings.

Pushing down

The pushing equipment is set up vertically and the dilatometer is pushed down into the ground. Pre-drilling is performed only through layers containing soil so coarse or stiff that there is a risk of damaging the dilatometer. Penetration shall be performed continuously and within given limits for its rate. The use of blows shall be avoided as far as possible and always specially noted. As an alternative to blows, the rod friction can be reduced either by using a local enlargement in the lower part of the chain of rods or by starting each penetration from one test level to the next by lifting the dilatometer and rods a few centimetres before they are pushed down.

Testing

Testing is normally performed at levels with depth intervals of 0.2 m. In other cases, the depth interval between two test levels shall be at least 0.15 m.

When the test level has been reached, the push rods are released in such a way that no pushing force is exerted except for the weight of the chain of rods itself. In extremely soft soils, the rods must be locked in order to prevent them from sinking due to their own weight. The application of gas pressure shall start within 15 seconds from the moment when the test level is reached.

The rate of pressure increase is regulated with the needle valve in such a way that the first signal, which indicates that the membrane has just started to move outwards, is obtained between 15 and 30 seconds after the start of pressure application. At this signal, the manometer is read off instantly, (the A-reading). The pressure application continues without interruption until the next signal arrives, which shall occur after another 15 to 30 seconds. At this instant, the manometer is read off again, (the B-reading), and the pressure is immediately vented off. Thereafter, the test at the particular level is finished and the dilatometer can be pushed down to the next test level.

6. Reporting Dilatometer Test Results

Protocol

When reporting dilatometer tests, the following information shall be given:

- Test site, project
- Designation of the test point
- Location of the test point in plan
- Levelled height of the ground surface at the test point
- Test date
- Operator
- Recorded ground water level and pore pressure distribution
- Date of the last calibration of the manometer(s)
- Zero reading of manometer(s)
- Calibration values for the membrane ΔA and ΔB before the test
- Calibration values for the membrane ΔA and ΔB after the test
- A and B readings and depth for each test level
- Possible use of blows for penetration and levels between which levels this has been performed
- Observations in connection with penetration, such as scraping noises or large variations in penetration resistance
- Difficulties in following the standard rate of pressure application (in highly variable soil conditions)
- Other problems, e.g. in terms of leakage or weak or otherwise indistinct signals

Graphical presentation

Results and evaluated parameters for each level are presented in a diagram. The diagram shall indicate the pressures p_0 and p_1, the material index I_D*), the horizontal stress index K_D and the dilatometer modulus E_D. Drawing of results and evaluated parameters is usually performed by using a computer programme. An example is shown in Figure 4.

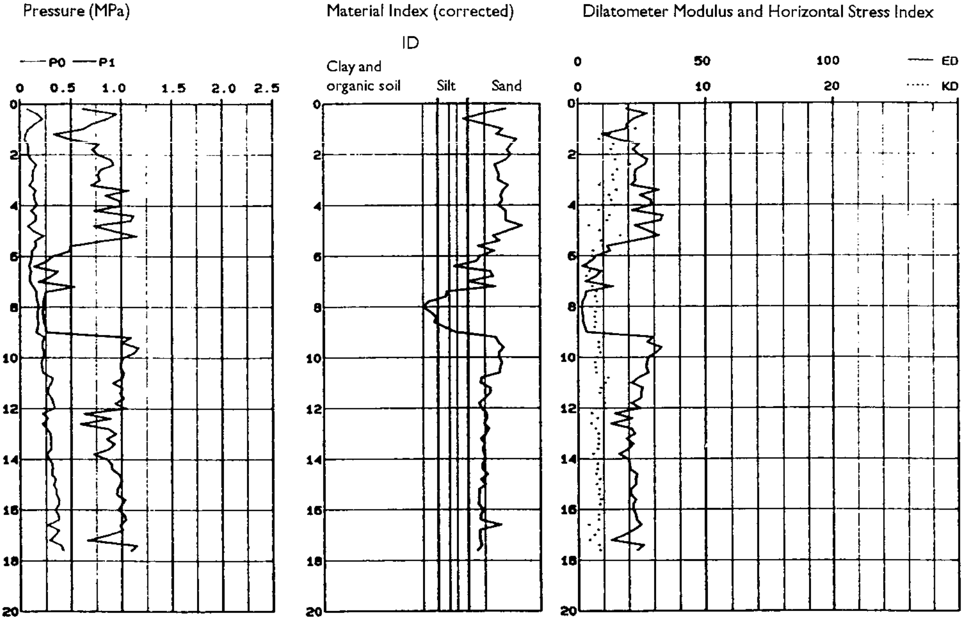

Figure 4. Example of presentation of results from dilatometer tests.

Additional evaluation and presentation of parameters is not part of the standard.

Reporting in plan shall conform with SGF's rules for designations.

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*) The material index can be corrected for overconsolidation effects according to

$I_{D(corr)} = I_D - 0.075(K_D - 2.5)$ at depth < 2.0 m and $K_D > 2.5$

$I_{D(corr)} = I_D - 0.035(K_D - 2.5)$ at depth ≥ 2.0 m and $K_D > 2.5$

If $K_D < 2.5$ and/or $I_D \leq 0.10$ then $I_{D(corr)} = I_D$

In all other cases, the restriction $I_{D(corr)} \geq 0.10$ applies

Both I_D and $I_{D(corr)}$ may be used in presenting the material index. It shall be clearly stated which alternative has been used.

SGF Rapport/Report

1:93 Rekommenderad standard för CPT-sondering.

1:93E Recommended Standard for Cone Penetration Tests.

2:93 Rekommenderad standard för vingförsök i fält.

2:93E Recommended Standard for Field Vane Shear Test.

1:95 Rekommenderad standard för dilatometerförsök.

1:95E Recommended Standard for Dilatometer Tests

2:95 Några pionjärprofiler i svensk geoteknik.
SJ Geotekniska Kommission 1914-1922.

The Swedish Geotechnical Society (SGF) was formed in 1950 and has currently 650 members with at least two years experience in geotechnics. In addition, there are some 35 corporate members comprising institutions, universities, official bodies, consultants, contracting companies and manufacturers with activities in the area of geotechnics.

The objective of the SGF is to promote development in geotechnics and foundation engineering through lectures, discussions and committee work, and to cooperate with Swedish, Nordic and other international bodies having a similar orientation.

The SGF is the Swedish representative of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE). Every member of the SGF is also a member of the international society.

The series of Reports published by the SGF contains recommendations for geotechnical standards, in addition to monographs and documentation from conferences, seminars and other events.

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