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EUROCODE 7 : GEOTECHNICAL DESIGN

Part 3 : DESIGN ASSISTED BY FIELD TESTING

Section 9 : FLAT DILATOMETER TEST (DMT)

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Section 9 Flat dilatometer test (DMT)

9.1 Scope

(1)P The flat dilatometer test DMT covers the determination of the in situ strength and deformation properties of fine grained soils using a blade shaped probe having a thin circular steel membrane mounted flush on one face.

(2) Results of DMT tests are mostly used to obtain information on soil stratigraphy, in situ state of stress, deformation properties and shear strength.

(3)P The basis of the test consists of inserting vertically into the soil a blade-shaped steel probe with a thin expandable circular steel membrane mounted flush on one face and determining, at selected depths or in a semi-continuous manner, the contact pressure exerted by the soil against the membrane when the membrane is flush with the blade and subsequently the pressure exerted when the central displacement of the membrane reaches 1.10 mm.

(4) The DMT test is most appropriate in clays, silts and sands where particles are small compared to the size of the membrane.

(5)P The tests shall be carried out in accordance with a method that complies with the essential requirements given in this section.

(6)P The test method used shall be reported in detail with the test results.

(7) The test method may be reported by reference to a published standard.

9.2 Definitions

9.2.1 Equipment and testing procedure

(1)P The main parts of a dilatometer equipment are defined in figure 9.1.

(2)P Dilatometer blade or dilatometer probe: the blade-shaped steel probe that is inserted into the soil to run a DMT test.

(3)P Membrane: the circular steel membrane that is mounted flush on one face of the blade and is expanded when applying a gas pressure at its back.

(4)P Switch mechanism: the apparatus housed inside the blade, behind the membrane, capable to activate and disconnect an electric contact which in turn shall respectively set off and on an audio and/or visual signal when the membrane expands and reaches two preset deflections equal to 0.05 mm and 1.10 mm respectively.

(5)P Pneumatic-electric cable: the cable that connects the control unit to the blade, delivers gas pressure at the back of the membrane, and provides electric continuity between the control unit and the switch mechanism.

(6)P Control and calibration unit: a set of suitable devices capable of supplying gas pressure to the back of the membrane and measuring the pressure when the switch mechanism activates and disconnect the electric contact behind the membrane.

(7)P Ground cable: a cable connecting the control unit to ground.

(8)P Pressure source: a pressurized gas tank filled with any dry nonflammable and noncorrosive gas.

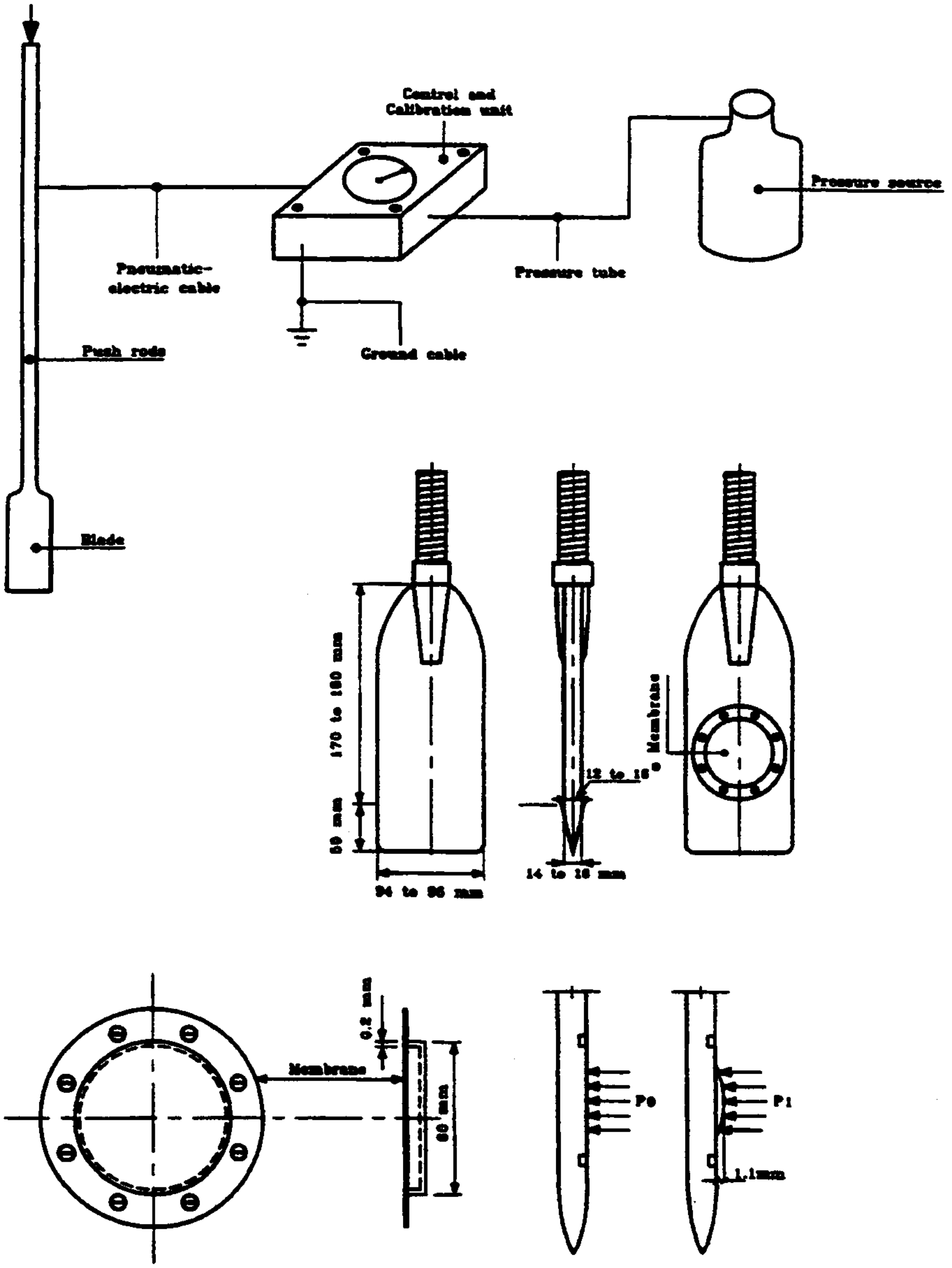

Figure 9.1: Dilatometer equipment and definition
of calculated in situ soil pressure

(9)P Membrane calibration: the procedure to determine the membrane calibration pressures equal to the suction and the pressure that must be applied in air to the back of the membrane to retract its centre to 0.05 mm expansion or to expand it 1.10 mm respectively.

(10)P Dilatometer profiling: the execution of a sequence of dilatometer tests from the same station at ground level along a vertical direction at closely spaced intervals with depth increments ranging between 150 and 300 mm.

9.2.2 DMT parameters

(1)P The following parameters are defined:

- A-pressure: the pressure that must be applied to the back of the membrane to expand its centre 0.05 mm in soil;
- B-pressure: the pressure that must be applied to the back of the membrane to expand its centre 1.10 mm in soil;
- ΔA-membrane-calibration-pressure: the suction, recorded as a positive value, that must be applied to the back of the membrane to retract its centre to the 0.05 mm deflection in air;
- ΔB-membrane-calibration-pressure: the pressure that must be applied to the back of the membrane to expand its centre to the 1.10 mm deflection in air;
- ΔA_{avg} and ΔB_{avg}: the averaged values of the membrane calibration pressures obtained from the respective values of ΔA and ΔB measured before and after each dilatometer profiling or single dilatometer test;
- Z_m-pressure: any gage pressure deviation from zero when venting the blade to atmospheric pressure;
- p_0: the soil pressure against the membrane when it is flush with the blade (e.g. at zero expansion), also termed contact pressure, as shown in figure 9.1;
- p_1: the soil pressure against the membrane when its centre is expanded 1.10 mm as shown in figure 9.1;
- u_0: the in situ pore water pressure prior to blade insertion at the elevation of the centre of the membrane;
- σ'_{v0}: the in situ effective vertical stress prior to blade insertion at the elevation of the centre of the membrane;
- I_{DMT} dilatometer material index: an index related to the type of soil;
- K_{DMT} dilatometer horizontal stress index: an index related to the in situ horizontal stress;
- E_{DMT} dilatometer modulus: a parameter related from theory to the modulus of elasticity of the soil.

9.3 Equipment

9.3.1 Dilatometer equipment

(1)P The equipment for dilatometer testing shall comprise:

- a dilatometer blade with suitable threaded adaptor to connect to push rods;
- a pneumatic-electrical cable;
- a ground cable;
- a control and calibration unit;
- a pressure source.

(2)P The dimensions of the blade, of the apex angle of the penetrating edge and of the membrane shall be comprised within the limits indicated in figure 9.1.

(3)P The pneumatic-electrical cable, which provides pneumatic and electrical continuity between the control unit and the dilatometer blade, shall have stainless steel connectors with wire insulators to prevent short circuit and washers to prevent gas leakage.

(4)P The control and calibration unit shall include any suitable connecting and measuring device to accomplish the following:

- connect to ground via the ground cable;
- connect to the dilatometer blade via the pneumatic-electrical cable;
- connect to the pressure source;
- control the rate of gas flow while monitoring and measuring the pressure of gas transmitted from the control unit to the blade and the membrane;
- signal the instants when the electric switch changes from on to off and vice versa.

(5)P The pressure measurement devices of the control and calibration unit shall allow to determine the pressure applied to the membrane with intervals of 10 kPa and a reproducibility of 2.5 kPa at least for pressures lower than 500 kPa.

(6)P The pressure source shall be provided with suitable regulator, valves and pressure tubing to connect to the control unit.

9.3.2 Insertion apparatus

(1)P The equipment for inserting the dilatometer blade shall comprise:

- a thrust machine to insert and advance the dilatometer blade into the soil;
- push rods with suitable adaptor to connect to the blade;
- hollow slotted adaptors for lateral exit of the pneumatic-electrical cable.

(2)P The thrust machine shall be capable of advancing the blade vertically with no significant horizontal or torsional forces.

(3) Penetration rates in the range 10 to 30 mm/s should be preferred. Driving should be avoided except when advancing the blade through stiff or strongly cemented layers which cannot be penetrated by static push.

(4)P Push rods shall be straight and stiff enough against buckling.

9.4 Test procedure

9.4.1 Calibration and checks

(1)P All the control, connecting and measuring devices shall be periodically checked and calibrated against a suitable reference instrument to assure that they provide reliable and accurate measurements.

(2)P The dilatometer blade and membrane shall be checked before inserting in the soil; the blade shall be mounted axially with the rods, it shall be planar and coaxial and have a sharp penetration edge; the membrane shall be clean of soil particles, free of any deep scratches, wrinkles or dimples and expand smoothly in air upon pressurization.

(3)P The maximum out of planar deviation of the blade, defined as the maximum clearance under a 150 mm long straight edge placed along the blade parallel to its axis, shall not exceed 0.5 mm; the maximum coaxiality error of the blade, defined as the deviation of the penetration edge from the axis of the rods to which the blade is attached, shall not exceed 1.5 mm.

(4)P The control unit and the tubing shall be checked for leaks before starting a sequence of dilatometer profilings by plugging the blade end of the pneumatic-electrical cable and checking for any pressure drop in the system. Leakage in excess of 100 kPa/min shall be considered unacceptable and shall be repaired before testing begins.

(5) With the dilatometer equipment assembled and ready for testing the switch mechanisms should be checked by hand pushing the membrane flush with the blade to check that the audio and/or visual signal on the control unit are activated.

9.4.2 Membrane calibration procedure

(1)P The membrane shall be calibrated to measure the values of the ΔA-suction and ΔB-pressure with the dilatometer equipment assembled and ready for testing immediately before inserting the blade into the soil and upon retrieval to the ground surface, both when running a dilatometer profiling or even a single test.

(2)P If the values of the membrane calibration pressures ΔA and ΔB obtained before inserting the blade into the soil fall outside the limits ΔA = 5 to 30 kPa and ΔB = 5 to 80 kPa respectively, the membrane shall be replaced before testing commences.

(3) After a membrane is replaced, the new one should be exercised to improve the stability of the ΔA and ΔB values. Such exercising may consist in pressurizing the membrane in air to 500 kPa for a few seconds. Care should be taken to avoid overexpansion and permanent deformations of the membrane.

(4)P After any membrane calibration the values of ΔA and ΔB shall be promptly recorded. All the obtained values of ΔA and ΔB shall be available on site.

(5)P During calibration the audio and/or visual signal activated by the electric switch shall stop and return sharply and unambiguously while sensing the 0.05 mm and 1.10 mm expansions respectively.

(6) When testing soft soils the membrane calibration procedure should be performed more than once to assure that stable values of ΔA and ΔB, falling within the prescribed limits, are constantly determined.

9.4.3 Performing the test

(1)P After the blade has been inserted into the soil and advanced to the selected test depth, the load applied to the push rods shall be released and the blade pressurized without delay to expand the membrane.

(2)P The rate of gas flow to pressurize the membrane shall be such that the A-pressure reading is obtained within 20 sec from reaching the test depth and the B-pressure reading is obtained within 20 seconds after the A-pressure reading.

(3)P Once the B-pressure has been determined the membrane shall be depressurized immediately, in order to prevent further expansion and permanent deformations, and the blade advanced to the next test depth or retrieved to the ground surface.

(4) Depending on the system used to advance the blade the pneumatic-electric cable connected to the blade should be pre-threaded through the push rods for protection or left outside, using a slotted adaptor to egress it, and taped to the rod every 1 m.

(5) When using a friction reducer to limit the thrust to advance the blade, it should be located at least 200 mm above the centre of the membrane.

(6)P After the blade has been retrieved to the ground surface and the membrane calibration procedure performed the values of ΔA and ΔB shall be recorded and compared with those measured previously. If the values of ΔA and ΔB measured <u>before</u> inserting the blade into the soil and <u>after</u> retrieval to the ground surface <u>differ by more than 25 kPa</u> then the test performed between the two successive calibration procedures shall be <u>discarded</u>.

9.5 Interpretation of the results

(1) Results of DMT tests can be interpreted using well established correlations to determine the subsoil stratigraphy, the deformation properties of cohesionless and cohesive soils, the in situ state of stress and the undrained shear strength of cohesive soils.

(2) The interpretation of the results of DMT tests requires a knowledge of the in situ pore water pressure u_0 and the effective vertical stress σ'_{v0} prior to blade insertion. The value of u_0 at any test depth should be determined from reliable pore water pressure measurements. The value of σ'_{v0} at any test depth should be estimated from the unit weight of the soil layers above that depth.

(3) When interpreting the results of DMT tests the values of p_0, p_1, u_0 and σ'_{v0} should correspond consistently to the same test location and membrane depth.

(4) The soil pressure p_1 against the DMT membrane when its centre is expanded 1.10 mm should be determined using the following relationship:

$$p_1 = B - \Delta B_{avg} - Z_m.$$

(5) The soil pressure p_0 against the DMT membrane when its centre is flush with the blade should be determined with a linear backextrapolation from the soil pressure against the membrane at the two preset deflections, 0.05 and 1.10 mm, hence using the following relationship:

$$p_0 = 1.05\ (A + \Delta A_{avg} - Z_m) - 0.05\ p_1.$$

(6) The material index I_{DMT}, the horizontal stress index K_{DMT} and the dilatometer modulus E_{DMT} should be calculated using the following relationships:

- $I_{DMT} = (p_1 - p_0)\ /\ (p_0 - u_0)$
- $K_{DMT} = (p_0 - u_0)\ /\ \sigma'_{v0}$
- $E_{DMT} = 34.7\ (p_1 - p_0).$

9.6 Reporting of the results

(1)P In addition to the requirements given in 2.6 the test report shall include the following information:

- rig and rod types;
- characteristics of systems used to advance the blade;
- predrilling depth and system to support the borehole if any;
- diameter and location of friction reducer if used;
- thrust applied to the push rods and at the top of the blade if measured;
- elevation of the groundwater table;
- procedures to calculate the pore pressure against the membrane at each test elevation;
- characteristics of the measuring system to obtain the in situ pore pressure when relevant;
- type and size of dilatometer blade and membrane;
- zero readings of pressure measurement devices;
- values of the ΔA- and ΔB-calibration-pressures measured before and after each dilatometer profiling or single test and corresponding average values;
- tabulated output of values of A- and B-pressure-readings;
- tabulated output of the calculated values of p_0- and p_1-pressure;
- any relevant observation of the operator such as incidents, equipment damage during testing, repairs and replacements, details not included in the above list which may affect the interpretation of test results.

9.7 Derived values of geotechnical parameters

9.7.1 Bearing capacity of shallow foundations

(1)P When the bearing capacity of shallow foundations is evaluated based on DMT results, an analytical method shall be used.

(2) When the sample analytical method of annex B in EC 7 Part 1 is used, the derived value of the undrained shear strength c_u of non cemented clays, for which the DMT test results show $I_{DMT} < 0.8$, can be determined using the following relationship:

$$c_u = 0.22\ \sigma'_{v0}\ (0.5\ K_{DMT})^{1.25}$$

or any other well documented relationship based on local experience.

9.7.2 Settlement of shallow foundations

(1) When applying the adjusted elasticity method of annex D in EC 7 Part 1 the one dimensional settlement of shallow foundations may be calculated using values of the one dimensional tangent modulus E_{oed} determined from results of DHT tests as shown in annex H. In cohesive soils such procedure should be applied when the stress increase induced by the foundation load is less than the preconsolidation pressure.

9.7.3 Pile foundations

(1) P When the ultimate bearing resistance of piles is evaluated from DMT results an analytical calculation method shall be applied to derive the values of base and shaft resistance.

ANNEX H
(Informative)

Flat Dilatometer Test (DMT)

The following is an example of correlations that may be used to determine the value of the one-dimensional tangent modulus $E_{oed} = d\sigma'/d\epsilon$ from results of DMT tests:

$$E_{oed} = R_M \, E_{DMT}$$

in which R_M is estimated either on the basis of local experience or using the following relationships:

- if $I_{DMT} \leq 0.6$: $R_M = 0.14 + 2.36 \log K_{DMT}$
- if $I_{DMT} \geq 3.0$: $R_M = 0.5 + 2 \log K_{DMT}$
- if $0.6 < I_{DMT} < 3.0$: $R_M = R_{M0} + (2.5 - R_{M0}) \log K_{DMT}$, in which $R_{M0} = 0.14 + 0.15 \, (I_{DMT} - 0.6)$
- if $K_{DMT} > 10$: $R_M = 0.32 + 2.18 \log K_{DMT}$

when values of $R_M < 0.85$ are obtained in the above relationships, R_M is taken equal to 0.85.

Reference:

Marchetti, S. (1980)
In situ test by flat dilatometer
Journal of the Geotechnical Engineering Division, Proc. ASCE, Vol. 106, N. GT3, pp 299-321.