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Geotechnical investigation and testing — Field testing — Part 11: Flat dilatometer test

Élément introductif — Élément central — Partie 11: Élément complémentaire

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 22476-11 was prepared by Technical Committee ISO/TC 182, *Geotechnical investigating and testing*, Subcommittee SC 1, and by Technical Committee CEN/TC 341, *Geotechnical investigating and testing* in collaboration.

This is the first edition.

ISO 22476 consists of the following parts, under the general title *Geotechnical investigation and testing — Field testing*:

EN ISO 22476 *Geotechnical investigation and testing - Field testing* has the following parts:

Part 1: Electrical cone and piezocone penetration tests

Part 2: Dynamic probing

Part 3: Standard penetration test

Part 4: Ménard pressuremeter test

Part 5: Flexible dilatometer test

Part 6: Self-boring pressuremeter test (TS)1)

Part 7: Borehole jack test

Part 8: Full displacement pressuremeter test (TS) 1)

Part 9: Field vane test

Part 10: Weight sounding test (TS)1)

Part 11: Flat dilatometer test (TS)1)

Part 12: Mechanical cone penetration test

Part 13: Plate loading test

Introduction

The flat dilatometer test 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.

Results of flat dilatometer tests are used mostly to obtain information on soil stratigraphy, in situ state of stress, deformation properties and shear strength.

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 membane reaches 1,10 mm.

The flat dilatometer test is most appropriate in clays, silts and sands, where particles are small compared to the size of the membrane

Geotechnical investigation and testing — Field testing — Part 11: Flat dilatometer test

1 Scope

This Standard comprises requirements for ground investigations by means of the flat dilatometer test (DMT) as part of the geotechnical investigation services according to EN 1997-1 and EN 1997-2.

2 Normative references

Not applicable.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this Technical Specification, the following terms and definitions apply

3.1.1
dilatometer blade (dilatometer probe)
blade –shaped steel probe that is inserted into the soil to run a flat dilatometer test

3.1.2
membrane
A thin circular steel piece that is mounted flush on one face of the blade and is expanded when applying a gas pressure at its back

3.1.3
switch mechanism
apparatus housed inside the blade, behind the membrane, capable of activating and disconnecting an electric contact when the membrane expands and reaches two preset deflections equal, respectively, to 0.05 mm (A-pressure reading) and 1.10 mm (B-pressure reading)

3.1.4
pneumatic-electric cable
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

3.1.5
control and calibration unit
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 disconnects the electric contact behind the membrane

3.1.6
earth wire
wire connecting the control unit to the earth

3.1.7
pressure source
pressurized gas tank filled with any dry nonflammable and noncorrosive gas

3.1.8
dilatometer sounding
a sequence of dilatometer tests executed from the same station at ground level along a vertical direction at closely spaced intervals with depth increments ranging between 100 mm and 300 mm

3.1.9
A-pressure
pressure (A) that is applied to the back of the membrane to expand its centre 0.05 mm in soil

3.1.10
B-pressure
pressure (B) that is applied to the back of the membrane to expand its centre 1.10 mm in soil

3.1.11
C-pressure
pressure (C) that is applied to the back of the membrane when the center of the membrane returns to the A-pressure position during a controlled, gradual deflection following the B-pressure

3.1.12
A-membrane-calibration-pressure
suction (ΔA) 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

3.1.13
B-membrane-calibration-pressure
pressure (ΔB) that must be applied to the back of the membrane to expand its centre to the 1.10 mm deflection in air

3.1.14
Z_m - pressure
gauge pressure deviation from zero when venting the blade to atmospheric pressure

3.1.15
soil pressure p_0
corrected A-pressure

NOTE The term "contact pressure" is also used.

3.1.16
soil pressure
p_1
corrected B-pressure

3.1.17
soil pressure
p_1
corrected C-pressure

3.1.18
in situ pore water pressure prior to blade insertion
u_0
in situ pore water pressure prior to blade insertion at the elevation of the centre of the membrane

3.1.19
in situ effective vertical stress
σ'_{vo}
vertical stress prior to blade insertion at the elevation of the centre of the membrane

3.1.20
dilatometer material index
I_D
index related to the type of soil

3.1.21
dilatometer horizontal stress index
K_D
index related to the situ horizontal stress

3.1.22
dilatometer modulus
E_D
parameter related from theory to the modulus of elasticity of the soil

3.2 Symbols

Symbol	Name	Unit
E_D	dilatometer modulus	kPa
I_D	dilatometer material index	-
K_D	horizontal stress index	-
A	A-pressure reading	kPa
B	B-pressure reading	kPa
C	C-pressure readings	kPa
p_0	soil pressure at zero membrane expansion	kPa
p_1	soil pressure at 1.10 mm membrane expansion	kPa
p_2		kPa
t_{flex}	contraflexure time in the pressure –time plot of a DMTA test	s
u_0	in situ pore pressure	kPa
Z_M	zero gauge value	kPa
ΔA	A-membrane-calibration-pressure	kPa
ΔB	B-membrane-calibration-pressure	kPa

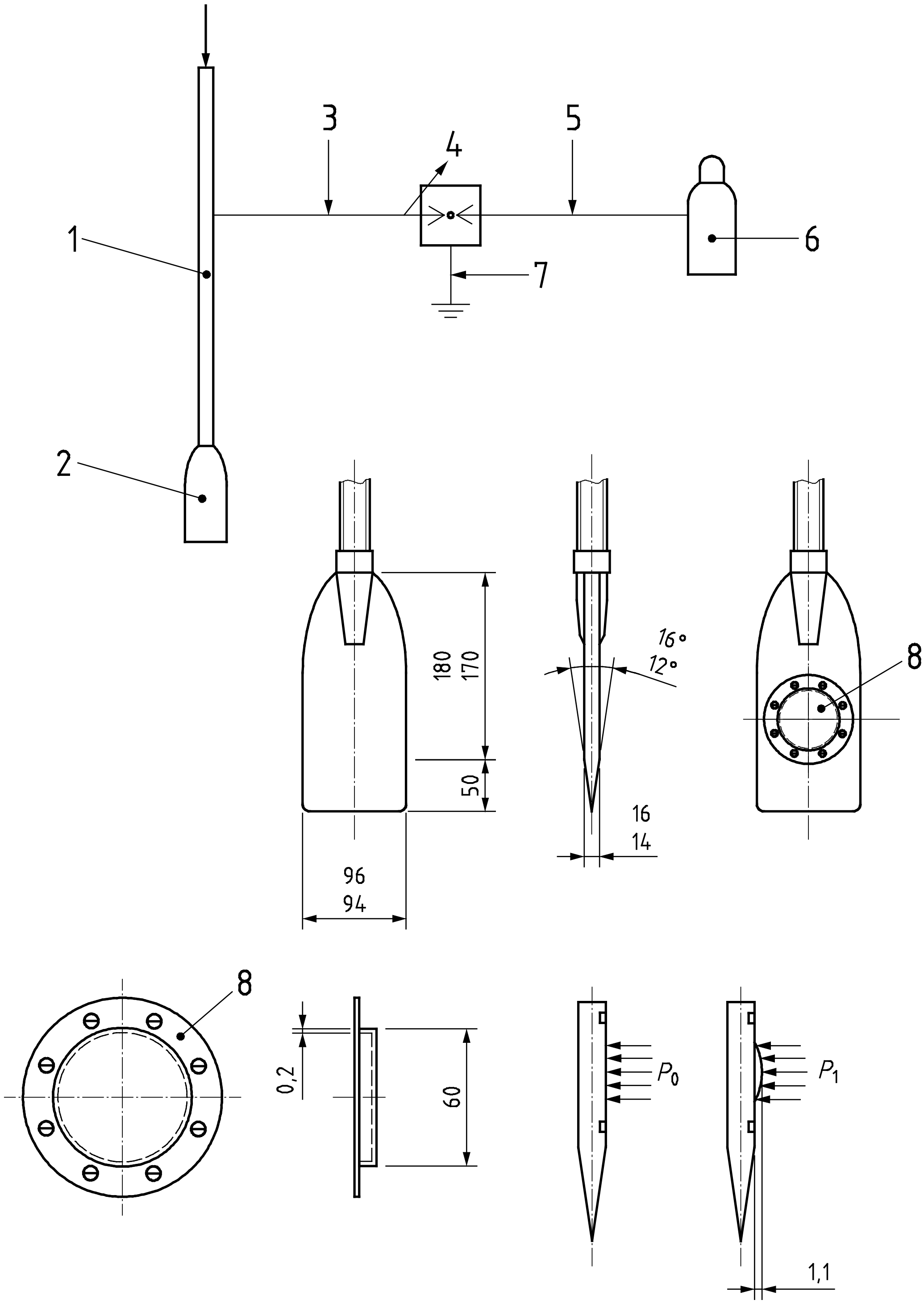
4 Equipment

4.1 Dilatometer equipment

The equipment shall comprise the following items:

a) Dilatometer blade with suitable threaded adaptor to connect to push rods;
b) Membrane;
c) Control and calibration unit;
d) Pressure source;
e) Pneumatic-electrical cable;
f) Earth wire;
g) Calibration Syringe.
h) (Optional) Automated data acquisition system

The dimensions of the blade, of the apex angle of the penetrating edge and of the membrane shall be within the limits shown in Figure 1.



Key

1 push rods

2 blade

3 pneumatic electric cable

4 control and calibration cable unit

5 pressure tube

6 pressure source

7 earth wire

8 membrane

Figure 1 — Dilatometer equipment and definition of calculated in situ soil pressure (all measures in mm)

The control and calibration unit shall have the following features:

- a socket for earthing;
- Ability to control of the rate of gas flow while monitoring and measuring the pressure of gas transmittted from the control unit to the blade and the membrane;
- Ability to signal the instants when the electric switch changes from on to off and vice versa.
- Pressure measurement devices able 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.

The pressure source shall be provided with a suitable regulator, valves and pressure tubing to connect to the control unit.

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

The calibration syringe is used for calibration of membrane rigidity, at the beginning and at the end of the test.

If the equipment incorporates a system for automatic data acquisition, such system should abide by the following specifications :

- It will register the gas pressure and the status of the electroacustical signal
- The linearity and hysteresis error of the transducers will be no more than ±0.50 %
- The analog-to-digital conversion will be at least 14 bit
- The acquisition frequency will be no less than 50 Hz

4.2 Insertion apparatus

The equipment for inserting the dilatometer blade shall comprise:

- 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.

The thrust machine shall be capable of advancing the blade vertically with no significant horizontal or torsional forces. Drill rigs and CPT/CPTu rigs are frequently employed for the purpose. To increase the capacity of penetration suitable dead loads and/or anchors may be used.

Push rods are required to transfer the thrust from the surface insertion equipment and shall be straight and resistant against buckling. Prior to each use, rod straightness shall be checked visually. Rods are also required to carry the pneumatic-electrical cable from the surface control unit to the dilatometer blade. It is recommended the use of rods of 1 m length. Above the ground level the rods should be guided to avoid buckling.

Frequently, push rods are the same used to push CPT/CPTu (see ISO 22476-1:2012) but other solutions are also possible.

To release the system of friction against the rods during the penetration phase, friction reducers may be used. Friction reducers are local increases in rod diameter. They are usually located in the first rod attached to the blade and shall be at least 200 mm above the membrane center.

Penetration rates in the range of 10 mm/s to 30 mm/s should be applied, wherever it is possible. Driving may be used when advancing the blade through stiff or strongly cemented layers which cannot be penetrated by static push.

A suitable load cell may be placed between the blade and the push rods. Such cell would measure the thrust applied during the blade penetration. This measurement is not necessary for common interpretations of the test result but it may facilitate interpretation when using both DMT and CPT soundings on a site

5 Test procedure

5.1 Maintenance and checks

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

The parts of the instrument inside the membrane shall be kept perfectly clean to insure proper electrical contacts. In particular these components shall be completely free from dirt, grains, tissue or rust.

The dilatometer blade and membrane shall be checked before penetrating 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.

The maximum out of plane 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.

The blade, the control unit and the pneumatic-electrical cable shall be checked for leaks before starting a sequence of dilatometer soundings 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 under 400 kPa pressure shall be considered unacceptable and shall be repaired before testing begins.

Continuity of the electrical circuit shall be checked, verifying that the off on switch signal is sharply detected.

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

5.2 Membrane calibration procedure

Membrane calibration consist in measuring the values ΔA –suction- and ΔB –pressure- that correspond, respectively, to the external pressure which must be applied to the membrane, in free air, to collapse it against its seating (i.e. A-position), and to the internal pressure which, in free air, lifts the membrane center 1.1 mm from its seating (i.e. B-position).
Membrane calibration shall be performed 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 sounding or even a single test.

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

After a membrane has been replaced, the new one shall be exercised to improve the stability of the ΔA and ΔB values. Such exercising shall consist in pressurizing five times the membrane in air to 400 kPa for a few seconds. Care shall be taken to avoid overexpansion and permanent deformations of the membrane.

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.

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.

5.3 Flat dilatometer test

5.3.1. Operations before testing

The operator shall perform all the checks described in section 5.1.

Depending on the system used to advance the blade, the pneumatic-electric cable connected to the blade shall 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.

The operator shall record the zero of the pressure gauge Z_M, with the gauge vented to the atmosphere.

The pressure source shall be connected to the control unit. It is recommended that the initial pressure level in the pressurizing circuit is set close to 3 MPa. This pressure may be later increased, if required to take the A and B readings.

The operator shall perform a membrane calibration as described in 5.2

5.3.2. Basic test procedure

The blade shall be inserted vertically into the soil and advanced to the selected test depth, during advancement the audio and/or visual signal shall be on.

After reaching the selected test depth the load applied to the push rods shall be released and the blade pressurized without delay to expand the membrane.

The gauge pressure at the time the acoustic or electrical signal stops is *A*. The gauge pressure at the time the signal resumes is *B*.

The rate of gas flow to pressurize the membrane shall be such that the A- pressure reading shall be obtained within approximately 15 seconds from reaching the test depth and the B-pressure reading within approximately 15 seconds after the A-reading. The rate of pressure increase shall be very slow in weak soils and faster in stiff soils.

Unless a C-reading is acquired, membrane shall be depressurized immediately after *B* has been determined, finishing the basic test procedure. The blade is then advanced to the next test depth or retrieved to the ground surface.

On a DMT sounding the DMT test shall typically be spaced at an interval of 200 mm. Smaller depth increments (no less than 100 mm) may be prescribed to obtain a more detailed soil profile. Larger increments (no more than 300 mm) if less detail is necessary.

5.3.3. C readings

C-readings may be performed as an extra measurement to aid in test interpretation. They are particularly useful when testing sands, since they can indicate the In situ pore pressure.

To obtain C-readings, the operator shall release the pressure slowly after the B-reading, and wait (approximately 30 seconds) until the pressure drops approaching the zero of the gauge. The C reading is obtained when the electrical signal resumes.

5.3.4. Operations after testing

After the blade has been retrieved to the ground surface a membrane calibration procedure, according to 5.2. shall be performed again. The values of ΔA and ΔB shall be recorded and compared with those obtained before testing. If the values of ΔA and ΔB measured before inserting the blade into the soil and after retrieval to the ground surface differ by more than 25 kPa then the test performed between the two successive calibration procedures shall be discarded.

5.4 DMT dissipation test (DMTA)

In low permeability soils (clays, silts) significant excess pore water pressure is induced by the DMT blade penetration. If drainage and/or consolidation characteristics are to be evaluated, DMT dissipation tests may be carried out at pre-selected depth in the deposit. A DMT dissipation test (DMTA test) consist in stopping the blade at a given depth, then taking a timed sequence of A-pressure readings.

During the dissipation test only the A-reading shall be taken, never expanding the membrane beyond the A-pressure position.

The time origin (t = 0) shall be the instant at which pushing is stopped. Then, without delay, the DMT operator shall slowly inflate the membrane to take the first A-reading. As soon as p_A is reached the operator shall deflate the membrane and record the instant of this reading, together with the A-value.

The DMT operator shall continue to take additional A-readings to obtain reasonably spaced data points for a time-pressure curve. A factor of 2 increase in time at each A-reading shall be satisfactory (e.g. 0.5, 1, 2, 4, 8, 15, 30 etc. minutes after stopping the blade). For each A-reading the operator shall record the exact stopwatch time (which shall not necessarily coincide with the above values).

The time-dissipation curve shall be plotted as the A-pressure vs. the log of the elapsed time for each reading. This curve shall normally assume an S-shape. For ease of interpretation, the dissipation test should not be stopped before the curve has flattened sufficiently to find its point of contraflexure, t_{flex}.

6 Test results

Results from a flat dilatometer test include primary results, derived results and interpreted results.

Primary test results comprise the pressures measured in the test corrected as follows.

The soil B-pressure shall be corrected to obtain the p_1 pressure using the following relationship:

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

The soil A-pressure p_0 shall be corrected to obtain the p_0 pressure using the following relationship:

$$p_0 = 1,05\,(A + \Delta A - Z_m) - 0,05\,p_1.$$

If measured, the soil C-pressure shall be corrected to obtain the p_2 pressure using the following relationship:

$$p_2 = C + \Delta A - Z_m$$

Derived test results are the material index I_D, the horizontal stress index K_D and the dilatometer modulus E_D.They shall be calculated using the following relationships:

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

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

$$E_D = 34,7\,(p_1 - p_0)$$

The derived results of flat dilatometer tests require 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 may be estimated from the location of the local water table, but shall be preferably determined from reliable pore water pressure measurements. It can also be evaluated from test results if C-pressure readings are acquired in free-draining soils. The value of σ'_{v0} at any test depth shall be estimated from the unit weight of the soil layers above that depth and the in-situ pore pressure at the test depth. An estimate of the unit weight may be obtained from the DMT measures using appropriate correlations (see Appendix 1)

Primary and derived test results 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. Appendix 1 recalls some of these correlations. In each case the appropriateness of these or other alternative interpretation techniques shall be adequately justified.

When interpreting the results of flat dilatometer tests the values of p_0, p_1, u_0 and σ'_{v0} shall correspond consistently to the same test location and membrane depth.

7 Report

7.1 General

The test results shall be reported to enable a third party to check and understand the results.

In the presentation of test results, the information should be easily accessible, for example in tables or as a standard archive scheme. Presentation in digital form is permissible for easier data-exchange.

Sub-clause 7.2 gives the information required in:

- The field data sheets
- The test report
- Every table and every plot of test results

The field data sheets shall be completed as the test is undertaken and shall be complete at the project site before the personnel and equipment are demobilised. During testing any particulars or deviations from this part of ISO 22476 should be recorded. The test report shall include all the field test sheets, including aborted tests and provide an overview of the site work, a description of the procedures adopted and all the information given in Section 7.2.

7.2 Reporting of test results

The following test reporting procedure is applicable to a dilatometer sounding in which flat dilatometer tests have been performed as described in 5.3. Reporting of dissipation tests (5.4) should follow the general principles given in 7.1

7.2.1 General information

		Field report	Test report	Every sounding
a	Reference to this part of ISO 22476	-	x	x
b	Particulars or deviations from this part of ISO 22476	x	x	-
c	Company executing the test	-	x	x
d	Name and signature of equipment operator executing the test	x	-	x
e	Name and signature of field manager responsible for the project	-	x	-
f	Groundwater elevation or other information used to estimate in-situ water pressure for each DMT test	-	x	x
g	Depth of pre-drilling (include method of drilling and any fluid used) casing or trenching if applicable	x	x	x
h	Type of materials encountered if possible	x	x	-
i	Depth of penetration and possible causes of interruptions (equipment breakdown etc)	x	x	x
j	Stop criteria applied such as target depth, maximum thrust force / hard stratum	x	x	-
k	Method of backfilling the hole, if applicable	x	-	x
l	Observations made during the test, such as presence of stone, noise from push rods, incidents, buckled rods, significant changes in zero or reference settings	x	-	x
m	Specific arrangements that deviate from common set up of thrust machine	x	x	-

7.2.2 Location of test

		Field report	Test report	Every sounding
a	Identification number of the test	x	x	x
b	Elevation of the Dilatometer test	-	x	x
c	Local or general coordinates of the test location	-	x	x
d	Reference system and tolerances	-	x	-

e	Reference elevation to a known datum	-	x	x
f	A brief site description including terrain, site boundaries and notable features such as water courses and any topographic features which may affect the values recorded or the interpretation of the test data, such as earthworks, excavations and natural features which could affect the local insitu stresses	x	-	-

The contract shall specify who is responsible for providing the coordinates and levels of the investigation points.

Notes should include any deviations from this Test Method.

7.2.3 Test equipment

		Field report	Test report	Every sounding
a	Dilatometer type	x	-	X
b	Geometry and dimensions of the dilatometer, as measured	x	-	-
c	Type of thrust machine used, pushing capacity, associated jacking and anchoring systems	x	-	-
d	Manufacturer of the dilatometer	x	x	-
e	Identification number of the dilatometer	x	-	-
f	Measuring range of the pressure gauges and zero offset when vented	x	x	-
g	ΔA and $\Delta \mathrm{B}$ blade calibrations (corrected for Zm), before, during (as obtained), and after each sounding	x	x	x
g	Type, diameter and linear weight of penetration rods;	x	X	-
h	Rod friction breaker diameter	x	-	x

7.2.4 Test procedure

		Field report	Test report	Every sounding
a	Date of test	x	x	x
b	Start time of the test	x	x	-
c	Depth of each test with reference to the ground surface	-	x	x
d	Dilatometer sounding identification	-	x	x

e	Prevailing weather conditions	x	x	-
f	Orientation of the blade when sounding A description of the procedures (tests and calibrations) adopted 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; Method used to estimate total vertical stresses	-	-	x

7.2.5 Test results

		Field report	Test report	Every sounding
a	Tabulated output of values of *A* and *B* pressure-readings	x	x	x
	C test reading (optional),			
b	Corrected test readings p_0, p_1, and (optional) p_2	x	-	-
c	Estimated bulk specific gravity or unit weight of soil,	x	x	-
d	Estimated total vertical stress, in-situ water pressure, and effective vertical stress,	x	x	-

7.3 Presentation of results

All measured and calculated values of results should be presented graphically as profiles against depth.

In the graphical presentation of test results, the following axis scaling should be used:

- Penetration depth *z*:	1 scale unit = 1 m
- *A* and *B* (P_C optional)	1 scale unit = 400kPa
- Corrected pressures p_0, p_1, and (optional) p_2	1 scale unit = 400kPa
- Insitu stresses (total, effective, porewater pressure)	1 scale unit = 100kPa
- DMT Material Index I_D	1 scale unit = 0.2
- DMT Horizontal Stress Index K_D	1 scale unit = 2.0
- DMT Modulus E_D	1 scale unit = 5.0 bar

One scale unit should be 1 cm.

Different scaling may be used in the presentation if the recommended scaling is used in an additional plot. The recommended scaling can for example be used for general presentation, whereas selected parts may be presented for detailed studies, using a different scaling.

Note A common presentation format is to use linear scales for pressures, stresses and DMT coefficients when plotted against depth and logarithmic scales when plotting DMT coefficients against other properties or values.

Graphs in which corrected pressures (p_0, p_1, p_2) I_D, K_D and E_D are plotted against depth should be presented side by side to assist in developing an understanding of the site.

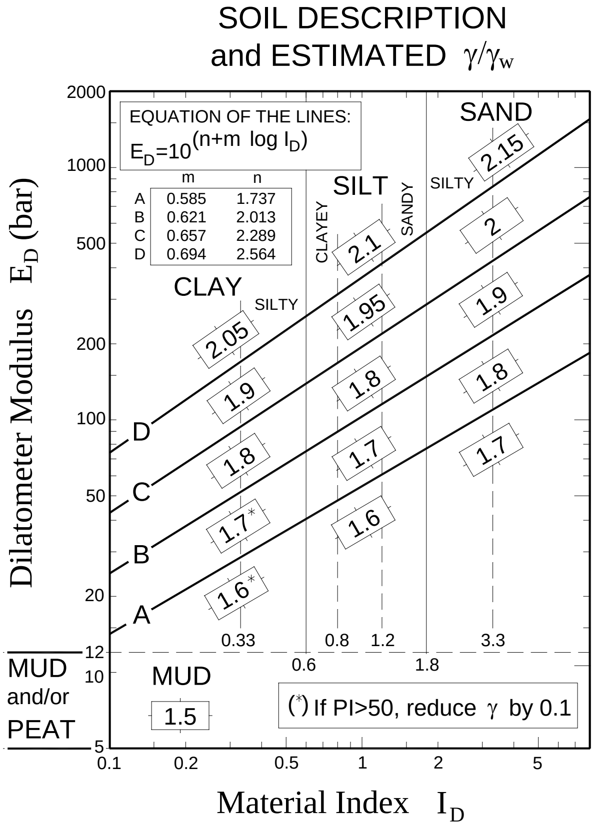
If interpreted results are presented, the relations used for that interpretation should be clearly indicated, sourced and/or justified within the report.

8 Appendix: Example interpretation formulae

Interpretation of DMT results in terms of different soil properties is based on a mixture of empirical and theoretical analysis. The nature of the soils being tested is the major factor affecting such interpretation. For non-cemented soils the following table collects some widely accepted soil property correlations (Marchetti et al. 2006; Marchetti, 1980). These correlations are included by way of example. Other correlations are available and may be more appropriate for a given test site.

Table 1 — DMT data reduction formulae

Symbol	**Description**	**Basic DMT reduction formula**	
K_0	Coef. Earth Pressure at rest	$K_{0,DMT}=(0.5K_D)^{0.47}-0.6$	For $I_D<1.2$
OCR	Overconsolidation ratio	$OCR_{DMT}=(0.5K_D)^{1.56}$	For $I_D<1.2$
c_u	Undrained shear strength	$C_{u,DMT}=0.22\sigma'_{v0}(0.5K_D)^{1.25}$	For $I_D<1.2$
ϕ	Friction angle	$\phi_{safe,DMT}=28°+14.6°\log K_D-2.1°\log^2 K_D$	For $I_D>1.8$
c_h	Horizontal coeff of consolidation	$c_{h,DMT}\approx 7cm^2/t_{flex}$	t_{flex} from A-log t DMT-A decay curve
k_h	Horizontal coeff of permeability	$K_h=c_h\gamma_w/M_h$ ($M_h\approx K_0M_D$)	
γ	Unit weight and description	(see chart below)	
M	Vertical drained Constrained Modulus	$M_{DMT}=R_ME_D$ If $I_D\leq 0.6$ $R_M=0.14+2.36\log K_D$ If $I_D\geq 3$ $R_M=0.5+2\log K_D$ If $0.6<I_D<3$ $R_M=R_{M,0}+(2.5-R_{M,0})\log K_D$ with $R_{M,0}=0.14+0.15(I_D-0.6)$ If $I_D>10$ $R_M=0.32+2.18\log K_D$ If $R_M<0.85$ Set $R_M=0.85$	


SOIL DESCRIPTION
and ESTIMATED γ/γw
EQUATION OF THE LINES:
ED=10(n+m log ID)
m n
A 0.585 1.737
B 0.621 2.013
C 0.657 2.289
D 0.694 2.564
CLAY
SILTY
SILT
CLAYEY
SANDY
SILTY
SAND
2.05
1.9
1.8
1.7*
1.6*
2.1
1.95
1.8
1.7
1.6
2.15
2
1.9
1.8
1.7
D
C
B
A
0.33
0.8
1.2
3.3
0.6
1.8
MUD
and/or
PEAT
MUD
1.5
(*) If PI>50, reduce γ by 0.1
Dilatometer Modulus ED (bar)
Material Index ID

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