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Geotehnično preiskovanje in preskušanje - Preskušanje na terenu - 4. del: Preskus z Ménardovim presiometrom (ISO/DIS 22476-4:2020)

Geotechnical investigation and testing - Field testing - Part 4: Prebored pressuremeter test by Ménard procedure (ISO/DIS 22476-4:2020)

Geotechnische Erkundung und Untersuchung - Felduntersuchungen - Teil 4: Vorgebohrter Pressiometerversuch nach Ménard (ISO/DIS 22476-4:2020)

Reconnaissance et essais géotechniques - Essais en place - Partie 4: Essai au pressiomètre Ménard (ISO/DIS 22476-4:2020)

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Part 4:
Prebored pressuremeter test by Ménard procedure

Reconnaissance et essais géotechniques — Essais en place —

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Foreword

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This second/third/... edition cancels and replaces the first/second/... edition (ISO #####:####), which has been technically revised.

The main changes compared to the previous edition are as follows:

— xxx xxxxxxx xxx xxxx

A list of all parts in the ISO ##### series can be found on the ISO website.

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Geotechnical investigation and testing — Field testing —

Part 4: Prebored pressuremeter test by Ménard procedure

1 Scope

This document deals with equipment requirements, the execution of and reporting on the Ménard pressuremeter test.

NOTE This part of ISO 22476 fulfils the requirement for the Ménard pressuremeter test, as part of geotechnical investigation and testing according to EN 1997-1 and EN 1997-2.

The present document describes the procedure for conducting a Ménard pressuremeter test in natural soils, treated or untreated fills and in rocks, either on land or off-shore.

The pressuremeter tests results of this document are suited to a quantitative determination of ground strength and deformation parameters. They may yield lithological information in conjunction with measuring while drilling performed when creating the hole (according to EN ISO 22476-15). They can also be combined with direct investigation (e;g; sampling according to EN ISO 22475-1) or compared with other in situ tests (see EN 1997-2, 2.4.1.4(2) P, 4.1 (1) P and 4.2.3(2) P).

The Ménard pressuremeter test is performed by the radial expansion of a cylindrical probe of a minimum slenderness of 6, placed in the ground (see Figure 1). During the injection of the liquid volume in the probe, the inflation of the measuring cell first brings the outer cover of the probe into contact with the pocket wall and then presses on them resulting in a soil displacement. Pressure applied to, and the associated radial expansion of the probe are measured either by volume or radial transducers and recorded so as to obtain the stress-strain relationship of the soil as tested.

Together with results of investigations with EN ISO 22475-1 being available or at least with identification and description of the ground according to ISO 14688-1 and ISO 14689-1 obtained during the pressuremeter test operations, the tests results of this document are suited for the quantitative determination of a ground profile, including

— the Ménard pressuremeter modulus E_M,

— the Ménard pressuremeter limit pressure p_{LM} and

— the Ménard creep pressure p_f.

This Standard refers to a probe historically described as the 60 mm (also called BX) G type probe with a pressure limitation of 5 MPa. If specified by the relevant authority or agreed for a specific project by the relevant parties, a higher pressure limitation may be required.

NOTE 1 G type probe refers to probes with an external cover creating guard cells (see 4.2).

NOTE 2 Ménard pressuremeter tests can be carried out with other diameter probes such as 32, 44 and 76 mm probes.

NOTE 3 Example of other probe and pocket drilling dimensions are indicated below:

Probe Designation	Probe Diameter mm	Drilling Diameter (mm) Min	Drilling Diameter (mm) Max
AX	44	46	52

Probe Designation	Probe Diameter mm	Drilling Diameter (mm)	
		Min	Max
NX	70/74	74	80

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ENV 13005:1999, *Guide to the expression of uncertainty in measurement.*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 14689, *Geotechnical investigation and testing — Identification, description and classification of rock*

EN ISO 22475-1, *Geotechnical investigation and testing – Sampling by drilling and excavation and ground water measurements – Part 1: Technical principles for execution*

EN ISO 24283-1, *Geotechnical investigation and testing — Qualification criteria —Part 1: Qualified technician*

EN ISO 24283-2, *Geotechnical investigation and testing — Qualification criteria —Part 2: Responsible expert*

EN ISO 24283-3, *Geotechnical investigation and testing — Qualification criteria – Part 3: Qualified enterprises*

EN ISO 22476-5, *Geotechnical investigation and testing – Field testing — Part 5: Prebored pressuremeter tests.*

EN ISO 22476-8, *Geotechnical investigation and testing – Field testing — Part 8: Full displacement pressuremeter test*

EN ISO 22476-15, *Geotechnical investigation and testing – Field testing — Part 15: Measuring while drilling*

EN ISO 10012, *Measurement management systems – Requirements for measurement processes and measuring equipment.*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

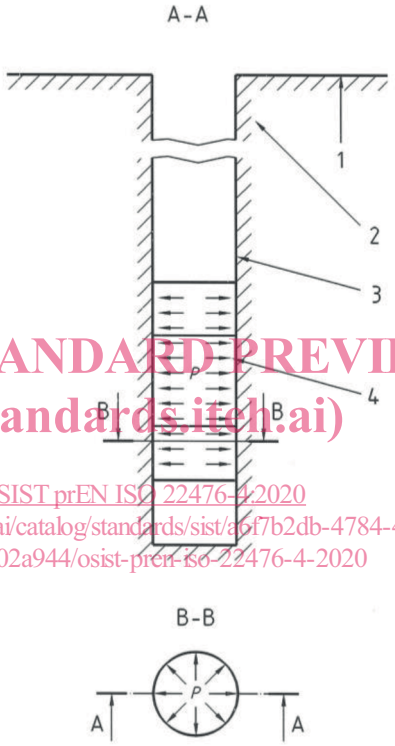
3.1.1
pressuremeter probe
cylindrical flexible probe which can be expanded by the application of hydraulic pressure and pressurised gas

3.1.2
pressuremeter control unit
set of suitable devices capable of supplying fluid and gas pressure to the probe

3.1.3
connecting lines
cable that connects the control unit to the probe, delivers fluid and gas pressure in the measuring and guard cells

3.1.4
pressuremeter test pocket
a circular cylindrical cavity formed in the ground to receive a pressuremeter probe

3.1.5
pressuremeter borehole
a borehole in which pressuremeter pockets with circular cross sections are made in the ground, and into which the pressuremeter probe is to be placed.



Key

1	Ground surface	p	applied pressure
2	Ground	A-A	axial section
3	Pocket	B-B	cross section
4	Expanding pressuremeter probe		

Figure 1 — Principle of a Ménard pressuremeter test

3.1.6
Ménard pressuremeter test
the process during which a pressuremeter probe is inflated in the pressuremeter test pocket and the resulting pocket expansion is measured as a function of time and pressure increments according to a defined programme (see Figure 4)

3.1.7
pressuremeter sounding
sequence of Ménard pressuremeter tests executed from the same station in the pressuremeter borehole

3.1.8
pressuremeter pressure reading
the pressure p_r as read at the CU elevation in the liquid circuit supplying the central measuring cell

3.1.9
pressure loss
the pressure loss is the difference between the pressure inside the probe and the pressure applied to the pocket wall

3.1.10
volume loss
the volume loss is the difference between the volume actually injected into the probe and the volume read on the measuring device

3.1.11
raw pressuremeter curve
the raw pressuremeter curve is the graphical plot of the injected volumes recorded at time 60 s, V_{60}, versus the applied pressure at each pressure hold, p_r

3.1.12
corrected pressuremeter curve
the corrected pressuremeter curve is the graphical plot of the corrected volumes V or radial displacements versus the corrected pressure p (see Figure 5)

3.1.13
pressuremeter creep
pressuremeter creep is defined as the difference in volumes recorded at 60 s and at 30 s at each pressure hold: $V_{60} - V_{30} = V_{60/30}$

3.1.14
corrected pressuremeter creep curve
a graphical plot of the corrected Ménard creep versus the corrected applied pressure at each pressure hold (see Figure 5)

3.1.15
pressuremeter log
a graphical report of the results of the pressuremeter sounding, together with all the information gathered during the drilling (see F.2)

3.1.16
Ménard pressuremeter modulus
modulus E_M obtained from the section between (p_1, V_1) and (p_2, V_2) of the pressuremeter curve (see Figure 5 and Annex D)

3.1.17
Ménard pressuremeter limit pressure
the pressure p_{LM} at which the volume of the test pocket at the depth of the measuring cell has doubled its original volume (see Annex D)

3.1.18
pressuremeter creep pressure
a pressure p_f defined as the intersection of two straight lines fitted on the creep curve (see Annex D)

3.1.19
operator
the person who carries out the test, qualified according to EN ISO TS 24283-1

3.1.20
casing
lengths of tubing inserted into a borehole to prevent the hole caving in or to prevent the loss of flushing medium to the surrounding formation, above pocket location

3.2 Symbols

For the purposes of this standard, the following symbols apply:

Table 1 — Symbols

Symbol	Description	Unit
a	Apparatus volume loss coefficient	cm^3/MPa
d_c	Outside diameter of the central measuring cell, including any additional protection such as a slotted tube	mm
d_{ci}	Outside diameter of the inner part of the probe with slotted tube	mm
d_i	Inside diameter of the calibration cylinder used for the volume loss calibration	mm
d_r	Outside diameter of the central measuring cell during expansion as read on the CU, before data correction	cm^3
d_t	Drilling tool diameter	mm
e	Wall thickness of the calibration cylinder used for the volume loss calibration	mm
l_c	Length of the central measuring cell of the probe, measured after fitting the membrane or the cover	mm
l_g	Length of each guard cell	mm
l_m	Length along the tube axis of the slotted section of the slotted tube	mm
l_p	Length of the calibration cylinder used for the volume loss calibration	mm
l_t	Length of the cover	mm
m_E	Minimum value, strictly positive, of the m_i slopes	cm^3/MPa
m_i	Slope of the corrected pressuremeter curve between the two points with coordinates (p_{i-1}, V_{i-1}) and (p_i, V_i).	cm^3/MPa
p	Pressure applied to the ground after correction	MPa
p_c	Liquid pressure in the central measuring cell of the pressuremeter probe	MPa
p_e	Correction for membrane stiffness usually called pressure loss of the probe	MPa
p_E	Pressure at the origin of the segment exhibiting the slope m_E	MPa
p_{el}	Ultimate pressure loss of the probe	MPa
p_f	Pressuremeter creep pressure	MPa
p_g	Gas pressure applied by the control unit indicator to the guard cells of the pressuremeter probe	MPa
p_h	Hydrostatic pressure between the control unit indicator and the central measuring cell of the pressuremeter probe	MPa
p_i	Pressuremeter corrected pressure	MPa
p_{LM}	Ménard pressuremeter limit pressure of the ground	MPa
p_{LMDH}	Ménard pressuremeter limit pressure as extrapolated by the double hyperbolic method	MPa
p_{LMH}	Ménard pressuremeter limit pressure as extrapolated by the hyperbolic best fit method	MPa
p_{LMR}	Ménard pressuremeter limit pressure as extrapolated by the reciprocal curve method	MPa
p_m	Pressure loss of the central measuring cell membrane for a specific expansion.	MPa
p_r	Pressure reading at the CU transducer elevation in the central measuring cell liquid circuit	MPa
p_t	Target pressure for each pressure hold according to loading program	MPa
p_0	Pressuremeter horizontal at rest pressure	MPa
p_1	Corrected pressure at the origin of the pressuremeter modulus pressure range	MPa
p_2	Corrected pressure at the end of the pressuremeter modulus pressure range	MPa

Table 1 *(continued)*

Symbol	Description	Unit
t	Time	s
t_i	Time required for incrementing to the next pressure hold	s
t_h	Time the loading pressure level is held	s
u_s	Pore water pressure in the ground at the depth of the test	MPa
z	Elevation, positively counted above datum	m
z_c	Elevation of the pressure measuring device for the liquid injected in the measuring cell	m
z_{cg}	Elevation of the pressure measuring device for the gas injected in the guard cells of the pressuremeter probe	m
z_N	Elevation of the ground surface at the location of the pressuremeter sounding	m
z_p	Elevation of the measuring cell centre during testing	m
z_w	Elevation of the ground water table (or free water surface in a marine or river environment)	m
CU	Pressure and volume control unit	---
E	Type of pressuremeter probe where the three cells are formed by three membranes in line	---
E_M	Ménard pressuremeter modulus	MPa
G	Type of pressuremeter probe where only the central measuring cell is formed by a dedicated membrane (see Figure 2)	---
V	Value, after zeroing and data correction, of the volume injected in the central measuring cell and measured 60 s after starting a pressure hold	cm^3
V_c	Original volume of the central measuring cell, including the slotted tube, if applicable	cm^3
V_i	Corrected volume	cm^3
V_m	The average corrected volume between V_1 and V_2	cm^3
V_p	Volume obtained in the volume loss calibration test (see Figure B.2)	cm^3
V_E	value, after data correction, of the volume injected in the central measuring cell for pressure p_E.	cm^3
V_L	Value, after data correction, of the volume injected in the central measuring cell when the original volume of the pressuremeter cavity has doubled	cm^3
V_r	Volume injected in the probe as read on the CU, before data correction	cm^3
V_t	Volume of the central measuring cell including the slotted tube	cm^3
V_1	Corrected volume at the origin of the pressuremeter modulus pressure range (see Figure 5)	cm^3
V_2	Corrected volume at the end of the pressuremeter modulus pressure range	cm^3
V_{30}	Volume injected in the central measuring cell as read 30 s after the beginning of the pressure hold	cm^3
V_{60}	Volume injected in the central measuring cell as read 60 s after the beginning of the pressure hold	cm^3
β	Coefficient used to determine the pressuremeter modulus pressure range.	---
γ	Unit weight of soil at the time of testing.	KN/m^3
γ_i	Unit weight of the liquid injected in the central measuring cell	KN/m^3
γ_w	Unit weight of water	KN/m^3
λ_g	Rate of change of pressure head of gas at p_k per metre depth	m^{-1}
ν	Poisson's ratio	---
σ_{vs}	Total vertical stress in the ground at test depth	kPa
σ_{hs}	Total horizontal stress in the ground at test elevation	kPa
Δp	Loading pressure increment	MPa

Table 1 *(continued)*

Symbol	Description	Unit
Δp_1	Initial pressure increment	MPa
$V_{60/30}$	Injected volume change from 30 s to 60 s after reaching the pressure hold - the pressuremeter creep	cm^3
$V_{60/60}$	60 second injected volume change between successive pressure hold	cm^3

4 Equipment

4.1 General Description

The pressuremeter shown schematically in Figure 2 shall include:

— pressuremeter probe;

— string of rods to handle the probe;

— control unit (CU);

— lines connecting the control unit to the probe.

Some means of measuring the depth of the test with appropriate accuracy shall be provided.

As represented on figure 2, other techniques of measurement may be used to follow the expansion.

NOTE Displacement transducers can provide an accurate measure of the expansion of the central section of the probe.

4.2 Pressuremeter probe

The probe shall be made up of cylindrical cells of circular cross-section along the same axis (see figure 2). The probe shall consist of a hollow steel core with passages to inject the proper fluids to inflate the cells. The steel core, on its outside curved surface, shall usually bear a network of grooves which uniformly distribute the liquid in the measuring cell under the membrane. The top of the core shall be threaded and coupled to the string of rods handling the probe from ground level.

If the measuring cell has slenderness at least equal to 6, the probe may be mono-cell. Conversely the probe has to be tri-cells to respect this criterion. A central measuring cell membrane shall isolate the fluid in the central measuring cell from the gas of the guard cells.

NOTE Compliance with this criterion ensures that the stress field is two-dimensional.

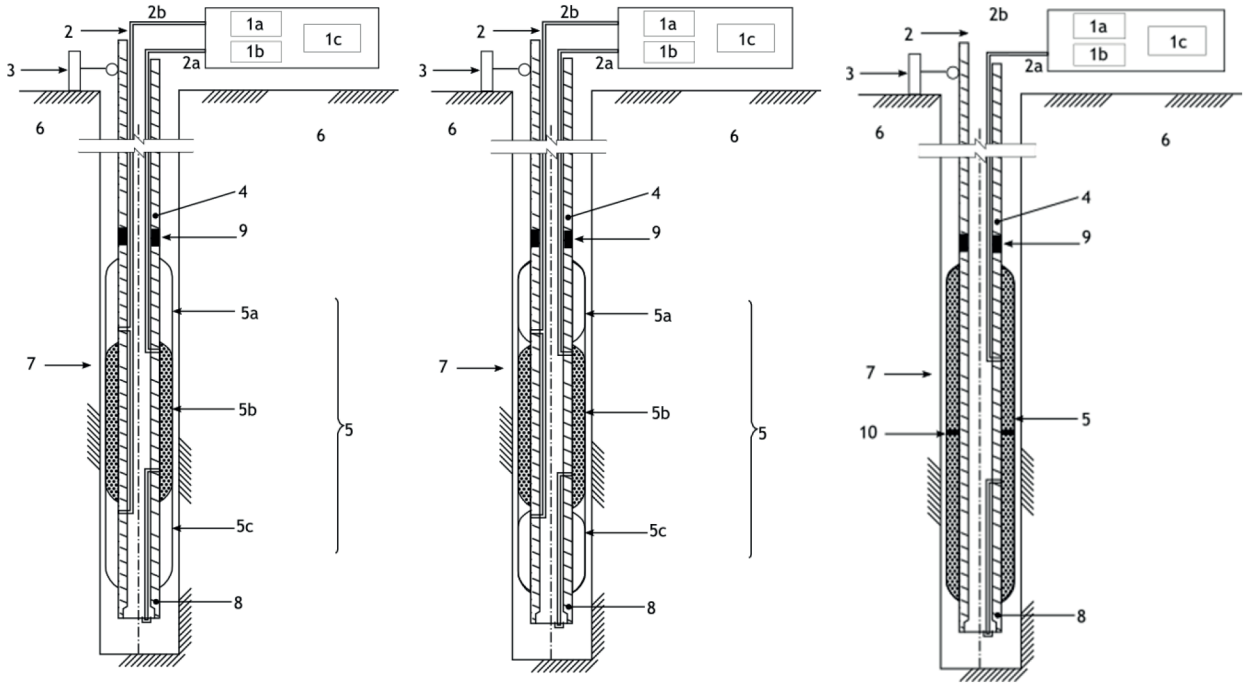
The central measuring cell shall be:

— covered by the cover creating guard cell (G type probe);

— covered by the cover with specific membranes for guard cells (E type probe);

— covered by the cover without guard cells (mono-cell type).

All three probes can be equipped for volumetric measurement or by radial transducer or any device providing a reliable measure either probe volume or radius. Pressure can be measure at ground or at probe level.



Key

1	Control unit (CU) :	1a	Pressurization, differential pressurization and injection devices
		1b	Pressure and volume measuring devices
		1c	Acquisition, storage and printing out of the data (required for CU type B and C)
2	Connecting lines :	2a	Line for liquid injection
		2b	Line for gas injection
3	Depth measurement system	5c	Lower guard cell
4	Rods	6	Ground
5	Pressuremeter probe	7	Pressuremeter test pocket
5a	Upper guard cell	8	Probe body, hollow
5b	Central measuring cell	9	Probe rod coupling
10	Transducers		

Figure 2 — Diagram of a Ménard pressuremeter

This measuring cell shall be inflated by injecting a liquid which is assumed to be incompressible.

NOTE Alternatively air can be used to inflate the measuring cell and the expansion followed by displacement transducers.

Three types of pressuremeter probes shall be used depending of ground type and conditions according to Annex C:

— hollow probe body with a flexible cover;

— hollow probe body with a flexible cover and an additional more rigid protection;

— hollow probe body with a flexible cover and a slotted steel tube.

These probes are respectively described in Figure 3a and Figure 3b and their geometrical features are given in Table A.1.

The 60 mm pressuremeter probe shall be capable of a volumetric expansion of at least 1.2 times its volume at rest V_c.

4.2.1 Probe with flexible cover

The probe includes:

— one measuring cell, with an outside diameter d_c and a minimum length l_c, which shall expand radially in a pocket and shall apply a uniform stress to the pocket wall;

— two guard cells if applicable with an outside diameter d_g and a length l_g located above and below the central measuring cell. These cells shall be designed to apply to the pocket wall a stress close to, but not greater than, the stress induced by the central measuring cell. These cells should be inflated by gas pressure.

The tri-cells probe should be fitted with a central measuring cell membrane and a flexible cover sleeve. The membrane and the flexible cover shall be fixed to the steel core with sealing system in order to avoid any leakage or pressure loss.

The flexible cover can be reinforced by textile or metallic canvas. For mono-cell probes the stiffness of the flexible cover shall allow a cylindrical shape of the measuring cell at least up to 700 cm^3.

4.2.2 Probe with flexible cover and an additional more rigid protection

A flexible protection made of thin plastic or steel strips either overlapping (up to half-way) or isolated, running between fixing rings may be added over the cover.

NOTE The flexible protection may be added to reduce damage to the cover from sharp fragments protruding from the pocket wall.

4.2.3 Probe with flexible cover and slotted tube

This probe shall consist of two parts:

— an inner part corresponding to previously described probes and

— an outer part which shall be made of a slotted steel tube (see Figure 3). When this slotted tube is pushed or driven into the soil it shall be fitted with an extension pipe ending with a point or a cutting shoe.

The outside steel tube shall carry at least 6 slots usually axial, evenly distributed round the circumference (Figure 3b).

Before and after expansion, the opening of each slot of the tube shall be less than or equal to 0,4 mm. After expansion the slotted tube and the slots shall be able to recover their original shape and size.

The assembly within the slotted tube shall be located so as to allow the probe to expand radially with a minimum of resistance. The mid plane of the measuring cell shall correspond to the mid plane of the slots. The location of the measuring cell may be fixed by flexible spacers when the slotted tube is fitted with extension pipe.