SLOVENSKI STANDARD
oSIST prEN ISO 22476-16:2023

01-junij-2023

Geotehnično preiskovanje in preskušanje - Preskušanje na terenu - 16. del: Strižni preskus v vrtini (ISO/DIS 22476-16:2023)

Geotechnical investigation and testing - Field testing - Part 16: Borehole shear test (ISO/DIS 22476-16:2023)

Geotechnische Erkundung und Untersuchung - Felduntersuchungen - Teil 16: Bohrscherversuch mit Phikometer (ISO/DIS 22476-16:2023)

Reconnaissance et essais géotechniques - Essais en place - Partie 16: Essai de cisaillement en forage (ISO/DIS 22476-16:2023)

Ta slovenski standard je istoveten z: **prEN ISO 22476-16**

ICS:

93.020	Zemeljska dela. Izkopavanja. Gradnja temeljev. Dela pod zemljo	Earthworks. Excavations. Foundation construction. Underground works

oSIST prEN ISO 22476-16:2023 **en,fr,de**

DRAFT INTERNATIONAL STANDARD
ISO/DIS 22476-16

ISO/TC **182** Secretariat: **BSI**

Voting begins on: **2023-03-20**

Voting terminates on: **2023-06-12**

Geotechnical investigation and testing — Field testing —

Part 16: **Borehole shear test**

Reconnaissance et essais géotechniques — Essais en place —

Partie 16: Essai de cisaillement en forage

ICS: 93.020

This document is circulated as received from the committee secretariat.

ISO/CEN PARALLEL PROCESSING

Reference number
ISO/DIS 22476-16:2023(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 182*, Geotechnics.*

The determination of the shear strength of soils is of paramount importance in Geotechnical investigation and testing of soils. The shear resistance of soils and materials, characterised by the friction angle φ and the cohesion c, represents an important parameter for the geotechnical engineer while studying the stability of construction works and structures in relation with soils and materials. Usually, this resistance is measured in the laboratory using triaxial tests or direct shear tests carried out on field samples and only if sampling, conservation and preparation make it possible to consider the samples as non remolded and sufficiently representative of the soil in place.

Since the 1960’s, various experimental devices have been designed and developed to determine the shear strength directly in situ from tests carried out in boreholes, in different soils at different depths.

The study of the bibliography literature shows that the majority of the existing borehole shear tests are based on the use of probes for applying and maintaining a normal pressure on the walls of the borehole and then to carry out a shear phase by a linear displacement of the probe on the soil against the walls of the borehole. The procedure is then repeated through a multistage increase of the normal pressure to obtain more values relating normal pressure and shear resistance.

The test equipment and apparatuses differ from each other by the geometry and size of the probes and by the shape of the friction part of these probes and by the procedure for applying normal pressure stages and shear phases.

One of the first devices of this kind is the Iowa Borehole Shear Tester (BST) developed in the USA (Handy & al 1967). The test is performed by placing a bilateral expandable probe, equipped with two diametrically opposed shear plates in a predrilled borehole, expanding the probe against the wall of the borehole and causing a shear failure in the soil by pulling the probe axially along the borehole. The size of the shear plates is relatively small (32,3 cm^2) and does not allow testing of soils with coarse elements, which may somewhat limit its field of application.

In the early 1970s, H. MORI, in Japan, developed an in situ shearing device called the IST which was used in many projects. The principle of the test is carried out by generating a shearing force while pulling upwards a cylindrical expandable probe provided with teeth driven into the wall of the borehole. but it is not reported whether the IST test continues to be performed currently.

Later on a self-boring in situ friction test (SBIFT), also developed in Japan (Yoshido Maeda & al. - 1998) allows the evaluation of soil characteristics as the initial horizontal at rest pressure, and deformation modulus and strength characteristics (cohesion and internal friction angle) of the soil. The SBIFT possesses a self-boring drilling functionality that can reduce the disturbance of the tested soil. However, very few data and results are available to currently validate this device and the characteristics of the soil it provides.

The same way as the SBIFT, a self-boring in situ shear pressuremeter (SBISP), was recently developed in China (Kunpeng Wang & al. - 2018), that allows the evaluation of pressuremetric characteristics as the initial horizontal at rest pressure, deformation yield pressure and modulus and also strength characteristics (cohesion and internal friction angle) of the soil. The SBISP possesses a self-boring drilling functionality that can greatly reduce the disturbance of the tested soil. However, very few data and results are available to currently validate this device and the characteristics of the soil it provides.

This standard ISO 22476-16 applies to the borehole shear test using the Phicometer procedure, commonly named the Phicometer Borehole shear test (PBST). This test has been invented and developed by Gérard PHILIPPONNAT in the 1980's (G. Philipponnat, 1986).

This test has been the subject, between 1986 and 1992, of several applied research programs to design the apparatus and its components and to develop and optimize a common test procedure that can be used in a majority of soils. Various articles have been published as a result of these researches and since then PBST tests continue to be carried out currently, for the determination of the shear strength parameters from the test and to derive values for the undrained shear strength and an estimation of the drained effective shear resistance parameters (see bibliography[3]: Philipponnat G, Zerhouni M.I., 1993). The test has been standardized in France since 1997 (Afnor, XP P94-120 standard).

This standard ISO 22476-16 applies to the borehole shear test using the Phicometer procedure, named the phicometer borehole shear test (PBST).

A list of all parts in the ISO 22476 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

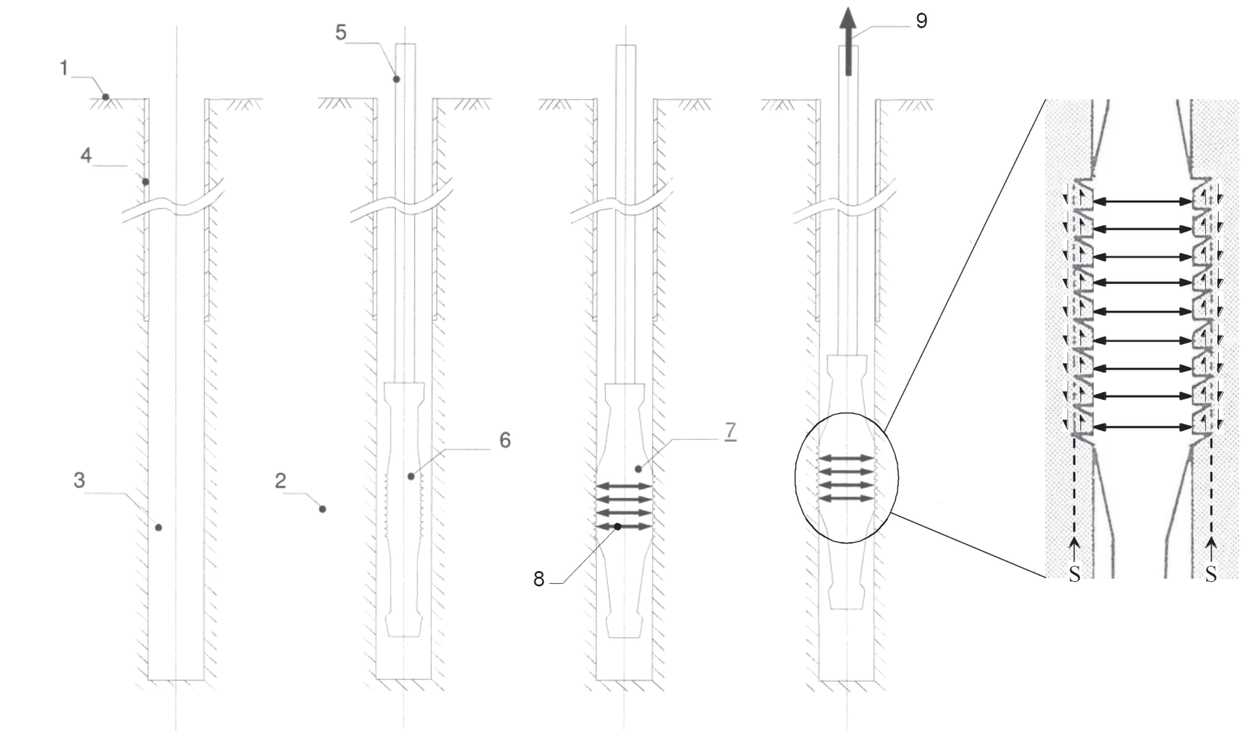
Geotechnical investigation and testing — Field testing —

Part 16:
Borehole shear test

1 Scope

This Part of ISO 22476 is applicable to the borehole shear test using the Phicometer procedure, commonly named the *phicometer test* (etymologically derived from *phi* for friction angle, *co* for cohesion and *meter* for measurement).

The test method covers a 4 steps procedure consisting of drilling a borehole, lowering the probe to the test depth, inflating it into the borehole wall and shearing the soil by applying a series of steps of controlled radial pressure and simultaneously pulling out the probe with a constant displacement rate. The test sequences are shown in figure 1.



a) borehole drilling phase: drilling a phicometer borehole with casing (if necessary) and setting up the PBST test pocket in the borehole bottom

b) probe placing phase: lowering the deflated probe to the test pocket depth

c) teeth insertion phase: radial expansion of probe and insertion of the annular teeth in the borehole wall

d) shearing phase: pulling on the probe inflated with a constant radial pressure at each multistage step

Key

1 ground surface
2 ground
3 borehole
4 casing (if necessary)
5 string of rods
6 probe (deflated state)
7 probe (inflated state)
8 radial pressure
9 pulling force
S shear plane

Figure 1 — General arrangement and sequences of the phicometer procedure borehole shear test

The test can be performed in all types of natural soils, fills and artificial soils, which can be saturated or not.

It does not apply to very soft soils, soft clays, very loose soils, rocks, slightly altered rocks and natural or artificial soils with a predominance of cobbles having a particle diameter greater than 150 mm.

Generally the test is applicable in soils with an order of magnitude of their in situ resistance characteristics as follows:

— Ménard pressuremeter limit pressure: 0,4 MPa < p_{LM} < 3 5 MPa approximately or more than 4 MPa in granular non cohesive soils;

— CPT Cone resistance: 1,5 MPa <qc <15 MPa approximately, depending on the type of soil (see annex E);

— SPT N: 8 <N <50 approximately, depending on the type of soil (see annex E).

NOTE The test may also be carried out in soils having a resistance outside these application limits. However, the representativeness of the results must be assessed or validated by the analysis of the PBST graphs (see paragraph 6.1).

This document applies only to tests carried out at a depth less than or equal to 30 m.

In soft soils at great depths, the test may not be applicable.

The parameters derived from this test are the shear strength properties: cohesion and friction angle.

2 Normative references

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 amendments) applies.

ISO 10012, *Measurement management systems — Requirements for measurement processes and measuring equipment*

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

ISO 14688-2, *Geotechnical investigation and testing — Identification and classification of soil — Part 2: Principles for a classification*

ISO 14689-1, *Geotechnical investigation and testing – Identification and classification of rock - Part 1: Identification and description*

ISO 22475-1, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for the sampling of soil, rock and groundwater*

ISO 22476-4, *Geotechnical investigation and testing — Field testing — Part 4: Prebored pressuremeter test by Ménard procedure*

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
Borehole shear test
The process during which a special shearing probe is installed in a borehole (see 3.1.4) at a defined depth and inflated against the borehole wall and pulled to determine the resulting shear force of the soil. This process is repeated with a succession of increased maintained normal pressure steps so as to obtain a pressure versus shear stress relation of the soil.

3.1.2
Phicometer borehole shear test (PBST)
The shear test performed in a borehole (see 3.1.1) with the Phicometer probe (see 3.1.3) and the Phicometer test procedure (see 5).

3.1.3
PBST device or Phicometer device
The whole equipment which is used to carry out a phicometer borehole shear test is called the phicometer. It consists of the following parts:

— a phicometer probe

— a pressure and volume Control Unit (CU)

— a line to connect the probe to the CU

— a pulling device placed on a reaction base on the ground surface and linked to the probe with rods

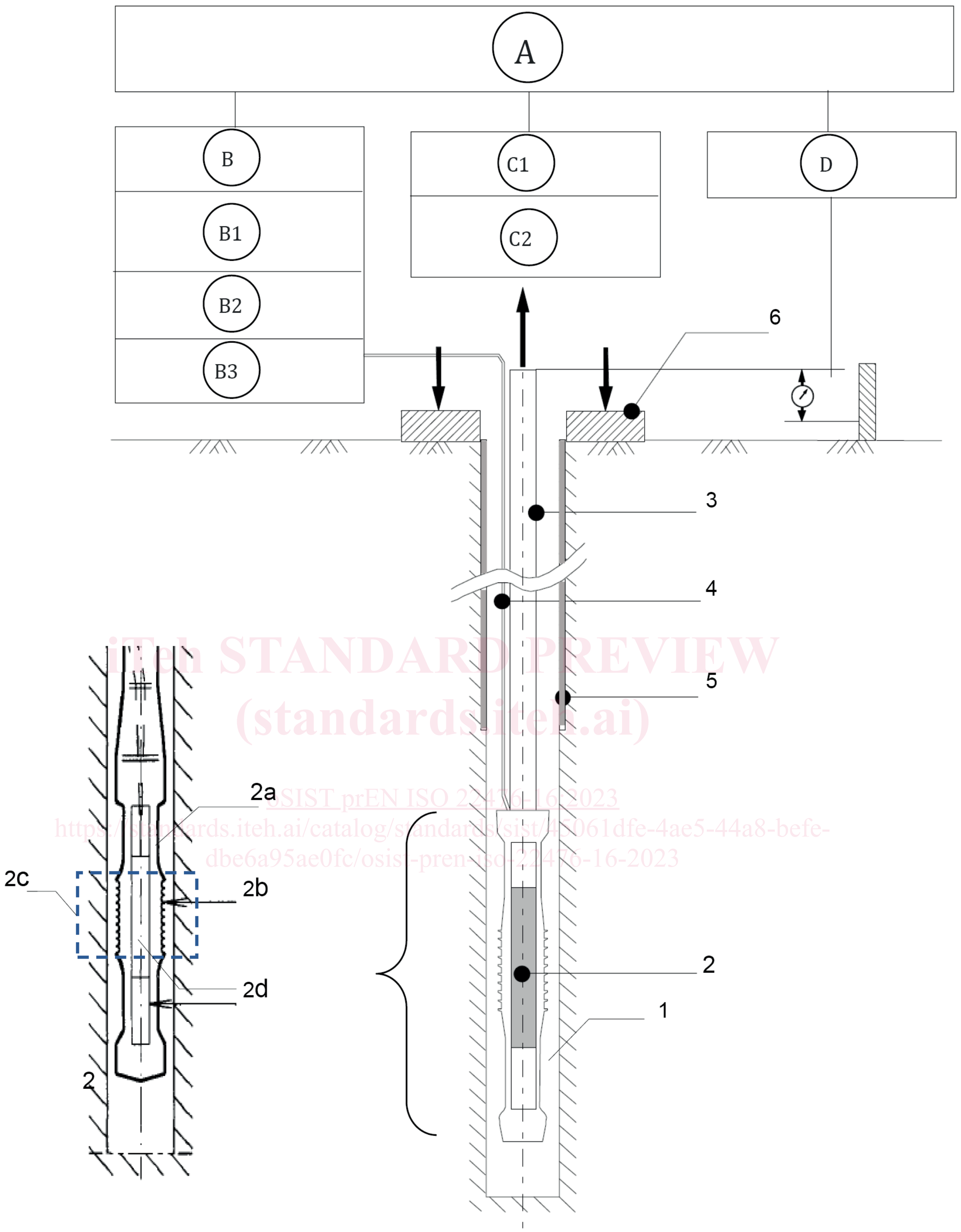
— a device to measure the pulling force

— a device to control the shearing displacement rate and to measure the displacement during the test

The equipment may also include a data logger.

A Phicometer Borehole Shear Test (PBST) device assembly is shown in figure 2:

An example of installation of the PBST equipment is shown in annex H.



Key

1	borehole	3	string of rods	5	borehole casing (if necessary)
2	phicometer probe	4	connecting line	6	reaction base
Detail of the Phicometer probe :		2a	expansible slotted tube	2c	shearing zone by the probe teeth
		2b	annular teeth	2d	inflatable measuring cell
A	data logger (optional)	B2	volume measurement	C2	pulling device with timer
B	pressure-Volume control Unit (CU)	B3	display of readings	D	axial displacement control

B1 pressure regulator & injection device C1 measurement of pulling force

Figure 2 — Diagram of the PBST test device assembly and its components

3.1.4
Phicometer borehole
The part of a borehole in which the test pocket will be set up. Its characteristics must meet the criteria given in 5.2 and the drilling must be carried out in accordance with the specifications and requirements of the annex C.

The drilling above the phicometer borehole can be carried out in a diameter greater or equal to the phicometer borehole diameter, without necessarily respecting the requirements of the phicometer borehole.

The distance between the top of the phicometer borehole and the centre of the test pocket (i.e: center of the shearing zone of the phicometer probe) shall not be less than 1,0 m.

In most cases, it is necessary to support the walls of the borehole, by using drilling mud and/or by placing a casing above the test pocket.

The choice between the different drilling techniques and tools is made according to the soil type, in order to achieve a cylindrical test zone on the borehole wall with minimum disturbance (see annex C) and create the test pocket. The direct driving of the probe into the soil is not allowed.

3.1.5
phicometer test pocket
The cylindrical cavity with a circular section made in a borehole and in which the probe of the phicometer is placed, brought into contact and pulled upwards during the test phases.

3.1.6
phicometer probe
(see 4.2 and figure 3)

3.1.7
phicometer test diagram
The set of plots resulting from the PBST test and allowing the determination of the shearing characteristics of the soil (see figure 6 and § 8)

3.1.8
phicometer cohesion
The in situ cohesion c_i obtained from the phicometer test diagram, see example in Figure 6.

3.1.9
phicometer angle of friction
The in situ angle of friction φ_i obtained from the phicometer test diagram, see example in Figure 6.

3.1.10
volume increase or decrease
Change in the measuring cell volume

3.1.11
depth of test
distance between the ground level and the centre of the shearing zone of the phicometer probe measured along the borehole axis.

3.1.12
operator
A technician trained in carrying out PBST tests, in accordance with this standard.

3.2 Symbols and abbreviations

For the purposes of this international standard the symbols of Table 1 apply.

Table 1 — Symbols

Symbol	Description	Unit
T	Pulling force on the probe	kN
T_l	Maximum pulling force	kN
V	Volume injected into the measuring cell of the probe as read on the control unit.	cm^3
V_d	Volume injected into the measuring cell of the probe at the beginning of the application of the pulling force.	cm^3
V_f	Volume injected into the measuring cell of the probe at the end of the application of pulling force.	cm^3
V_{30}	Volume injected into the measuring cell of the probe after 30 s under a constant pressure phase	cm^3
V_{60}	Volume injected into the measuring cell of the probe after 60 s under a constant pressure phase	cm^3
d_{s0}	Initial diameter of the probe at rest in the shearing zone (see figure 3)	mm
c_i	Phicometer cohesion measured in situ by the PBST	kPa
d_s	Diameter of the probe in the shearing zone after injection of a volume V (see figure 3)	mm
d_t	Diameter of the pocket at the level of the test.	mm
d_c	Outside diameter of the measuring cell of the probe	mm
l_t	Slots length of the expansible shear tube	mm
l_c	Distance between the rings of the measuring cell of the probe	mm
l_s	Conventional length of the shearing zone (see figure 3)	mm
N	Standard penetration test SPT Blow count (ISO 22476-3)	-
p_c	Conventional radial pressure applied to the ground after corrections.	kPa
p_e	Probe stiffness pressure loss determined by calibration.	kPa
p_h	Pressure due to the injection liquid column in the probe (between z_c and z_s).	kPa
p_{lM}	Ménard pressuremeter limit pressure (ISO 22476-4).	MPa
p_r	Pressure of the liquid injected into the Phicometer measuring cell, read at the level z_c of the Control unit (CU)	kPa
p_z	Pressure of the liquid at the centre of the measuring cell	kPa
q_c	Cone penetration resistance (ISO 22476-1 or ISO 22476-12)	MPa
t	Time.	s
v	Rate of axial displacement of the probe during the pulling phase.	mm/min
z	Elevation, ascending above datum	m
z_0	Elevation of the ground surface level at the location of the test.	m
z_c	Elevation of the pressure measuring device of the liquid injected into the Phicometer measuring cell.	m
z_e	Elevation of the drilling fluid in the borehole.	m
z_{ei}	initial level of water or mud measured in the borehole before the beginning of the test	m
z_{ef}	final level of water or mud measured in the borehole after the end of the test	m