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## 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*

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## Foreword

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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 document 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](http://www.iso.org/directives)).

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This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical Investigation and Testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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

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## Introduction

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  $\varphi$  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 (~~[13] Handy & al., 1967~~),<sup>[13]</sup> 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<sup>2</sup>) and does not allow testing of soils with coarse elements, which can somewhat limit its field of application.

In the early 1970s, H. ~~Mori [15], Mori [15]~~ 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.

A self-boring in situ friction test (SBIFT), also developed in Japan (~~[14] Yoshida Maeda & al., 1998~~),<sup>[14]</sup> 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.

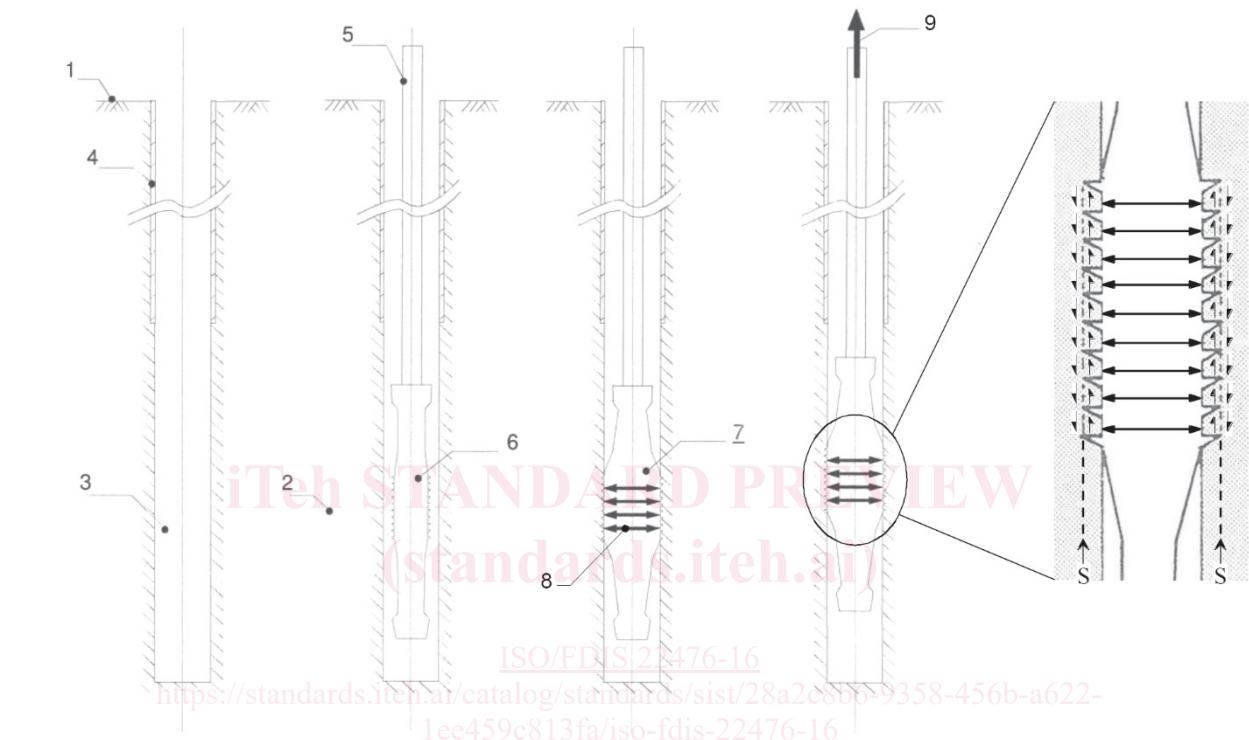
The same way as the SBIFT, a self-boring in situ shear pressuremeter (SBISP), was recently developed in China (~~[12] Kunpeng Wang & al., 2018~~),<sup>[12]</sup> that allows the evaluation of pressuremetric characteristics as the initial horizontal at rest pressure, deformation yield pressure and modulus 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 document 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 (~~[10] G. Philipponnat, 1986~~),<sup>[10]</sup>

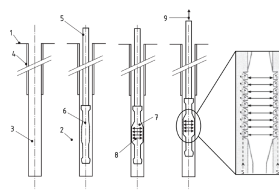
This test has been the subject, between 1986 and 1992, of several applied research programs to design the apparatus and its components and to develop and optimize a common test procedure that can be used in a majority of soils. Various articles have been published as a result of these researches and 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 ~~([9] G. Philipponnat, M.I. Zerhouni, 1993).~~<sup>[9]</sup> The test has been standardized in France since 1997.

The borehole shear test using the phicometer covers a four-phases 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



- 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 | 4 | casing (if necessary)  | 7 | probe (inflated state) |
| 2 | ground         | 5 | string of rods         | 8 | radial pressure        |
| 3 | borehole       | 6 | probe (deflated state) | 9 | pulling force          |

S ~~Cylindrical~~cylindrical shear surface

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

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# Geotechnical investigation and testing — Field testing —

## Part 16: Borehole shear test

### 1 Scope

This document 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 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 fine soils, very loose coarse soils, medium strong to very strong 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:  $0,4 \text{ MPa} < p_{\text{IM}} < 3,5 \text{ MPa}$  approximately or more than 4 MPa in granular non-cohesive soils;
- — CPT Cone resistance:  $1,5 \text{ MPa} < q_c < 15 \text{ MPa}$  approximately, depending on the type of soil (see [Annex E](#)); [Annex E](#));
- — SPT N:  $8 < N < 50$  approximately, depending on the type of soil (see [Annex E](#)); [Annex E](#)).

The test may also be carried out in soils having presenting a resistance outside these application limits. However, as long as the representativeness of the results shall be assessed or validated by the analysis of the PBST graphs (see [8](#)); [Clause 8](#)).

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

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

### 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.

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

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

### 3 Terms, definitions, symbols and abbreviated terms

#### 3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ~~—~~ISO Online browsing platform: available at <https://www.iso.org/obp>~~https://www.iso.org/obp~~
- ~~—~~IEC Electropedia: available at <https://www.electropedia.org/>~~https://www.electropedia.org/~~

##### 3.1.1

###### **borehole shear test**

process during which a special shearing probe is installed in a borehole at a defined depth and inflated against the borehole wall and pulled to determine the resulting shear resistance of the soil

Note 1 to entry:— 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**

shear test performed in a *phicometer borehole* (3.1.4) with the *phicometer probe* (3.1.6) and the phicometer test procedure (see 5)

Note 1 to entry: See Clause 5 for the *phicometer test procedure*.

##### 3.1.3

###### **phicometer**

whole equipment which is used to carry out a *phicometer borehole shear test PBST* (see 4)(3.1.2)

##### 3.1.4

###### **phicometer borehole**

~~Part~~part of a borehole in which the *phicometer test pocket* (3.1.5) is to be set up (see 5.2)

Note 1 to entry: See 5.2.

##### 3.1.5

###### **phicometer test pocket**

cylindrical cavity with a circular section made in a borehole and in which the *phicometer probe* (3.1.6) is placed, brought into contact and pulled upwards during the test phases

##### 3.1.6

###### **phicometer probe**

cylindrical expandable probe with annular shearing teeth, used to carry out a *phicometer borehole shear test* (See 4.2 and Figure 3)(3.1.2)

Note 1 to entry: See 4.2 and Figure 3.

##### 3.1.7

###### **phicometer test diagram**

set of plots resulting from the *PBST* (3.1.2) test and allowing the determination of the shear resistance of the soil—

Note 1 to entry: See [8 Clause 8](#) and [Figure 6\)Figure 6](#).

### 3.1.8

#### phicometer cohesion

in situ cohesion  $c_i$  obtained from the *phicometer test diagram* [\(3.1.7\)](#)

### 3.1.9

#### phicometer angle of friction

in situ angle of shear friction  $\varphi_i$  obtained from the *phicometer test diagram* [\(3.1.7\)](#)

### 3.1.10

#### depth of test

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

### 3.1.11

#### operator

technician trained in carrying out PBST tests, in accordance with this document

## 3.2 Symbols and abbreviated terms

For the purposes of this document, the symbols of [Table 1Table 1](#) apply.

Table 1 — Symbols

Symbol	Description	Unit
$T$	Pulling force on the probe	kN
$T_1$	Maximum pulling force	kN
$V$	Volume injected into the measuring cell of the probe as read on the control unit	cm <sup>3</sup>
$V_d$	Volume injected into the measuring cell of the probe at the beginning of the application of the pulling force ( $V_d = V_{60}$ )	cm <sup>3</sup>
$V_f$	Volume injected into the measuring cell of the probe at the end of the application of pulling force	cm <sup>3</sup>
$V_{30}$	Volume injected into the measuring cell of the probe after 30 s under a constant pressure phase	cm <sup>3</sup>
$V_{60}$	Volume injected into the measuring cell of the probe after 60 s under a constant pressure phase	cm <sup>3</sup>
$d_{s0}$	Initial diameter of the probe at rest in the shearing zone (see <a href="#">Figure 3)Figure 3</a> )	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 <a href="#">Figure 3)Figure 3</a> )	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