SLOVENSKI STANDARD
oSIST prEN ISO 18674-5:2019

01-januar-2019

Geotehnično preiskovanje in preskušanje - Geotehnične meritve - 5. del: Merjenje spremembe napetosti s TPC (ISO/DIS 18674-5:2018)

Geotechnical investigation and testing - Geotechnical monitoring by field instrumentation - Part 5: Stress change measurements by Total Pressure Cells (TPC) (ISO/DIS 18674-5:2018)

Geotechnische Erkundung und Untersuchung - Geotechnische Messungen - Teil 5: Spannungsänderungsmessungen mittels Druckmessdosen (ISO/DIS 18674 5:2018)

Reconnaissance et essais géotechniques - Surveillance géotechnique par instrumentation in situ - Partie 5: Mesures avec capteurs hydrauliques (ISO/DIS 18674-5:2018)

Ta slovenski standard je istoveten z: **prEN ISO 18674-5**

ICS:

13.080.20	Fizikalne lastnosti tal	Physical properties of soils
93.020	Zemeljska dela. Izkopavanja. Gradnja temeljev. Dela pod zemljo	Earthworks. Excavations. Foundation construction. Underground works

oSIST prEN ISO 18674-5:2019 **en**

DRAFT INTERNATIONAL STANDARD

ISO/DIS 18674-5

ISO/TC **182**

Secretariat: **BSI**

Voting begins on:
2018-09-25

Voting terminates on:
2018-12-18

Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 5:
Stress change measurements by Total Pressure Cells (TPC)

Reconnaissance et essais géotechniques — Surveillance géotechnique par instrumentation in situ — Partie 5: Mesures avec capteurs hydrauliques

ICS: 13.080.20; 93.020

This document is circulated as received from the committee secretariat.

ISO/CEN PARALLEL PROCESSING

Reference number
ISO/DIS 18674-5:2018(E)

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Published in Switzerland

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 182, *Geotechnics.*

A list of all parts in the ISO 18674- series, published under the general title *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation,* can be found on the ISO website.

Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 5:
Stress change measurements by Total Pressure Cells (TPC)

1 Scope

This document specifies the measurement of stress changes by means of total pressure cells (TPC). It refers to cells which are permanently installed either in the ground, in adjacent engineered structures or in contact planes between any two media. General rules of performance monitoring of the ground, of structures interacting with the ground, of geotechnical fills and of geotechnical works are presented in ISO 18674-1:2015.

If applied in conjunction with ISO 18674-4:2019, this document allows the determination of effective stress acting in the ground.

Indirect stress monitoring methods (see 18674-1:2015, Table B.2) are not subject of this document.

This document is applicable to:

— monitoring changes of the state of stress in the ground and in geo-engineered structures (e.g. in earth fill dams or tunnel lining);

— monitoring contact pressures at the interface between two media (e.g. earth pressure on retaining wall; contact pressure at the base of a foundation);

— checking geotechnical designs and adjustment of construction in connection with the Observational Design procedure;

— evaluating stability during or after construction.

NOTE This document fulfils the requirements for the performance monitoring of the ground, of structures interacting with the ground and of geotechnical works by the means of total pressure cells as part of the geotechnical investigation and testing according to EN 1997-1 and EN 1997-2, see References [1] and[2].

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

EN ISO 18674-1:2015, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 1: General rules*

ISO 18674-4:2019, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 4: Measurement of pore water pressure: Piezometer*

ISO 22475-1:2006, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution*

ISO 22476-1:2012, *Geotechnical investigation and testing — Field testing — Part 1: Electrical cone and piezocone penetration test*

3 Terms and definitions

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

For the purposes of this document the terms and definitions given in ISO 18674-1:2015 and the following apply:

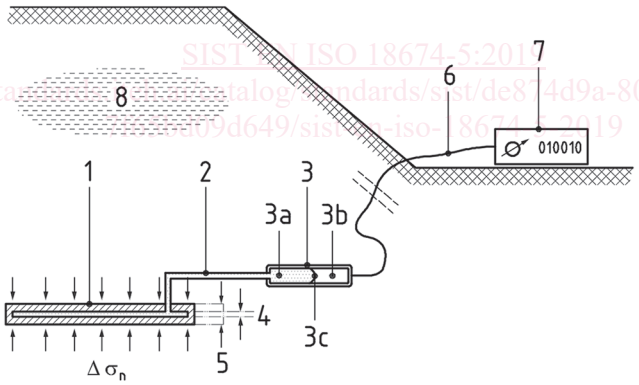
3.1
total pressure cell
TPC
field instrument for stress change measurements where a total pressure cell is the sensing element of the system

Note 1 to entry: A total pressure cell consists of a pressure pad (1), a pressure tubing (2) and a pressure measuring device (3) (see Figure 1 and Reference [3]).

Note 2 to entry: The pressure pad (1) consists of two steel platens, welded together around their peripheries, where the intervening cavity is filled with a liquid. The cavity is connected to the inner chamber (3a) of the pressure measuring device via a liquid-filled pressure tubing (2). Inner and outer chambers (3a and 3b) of the pressure measuring device are separated by a flexible diaphragm (3c).

Note 3 to entry: Total pressure cells are stationary instruments which are embedded in a medium (see 3.2), placed at the interface between any two media (see 3.3) or installed in boreholes (see 3.4).

Note 4 to entry: The target of the measurement is the change of the total normal stress $\Delta\sigma_n$ of the medium acting onto the flat side of the pad.



Key

1 pressure pad
2 pressure tubing
3 pressure measuring device
  3a inner chamber
  3b outer chamber
  3c diaphragm
4 height of the pressure pad cavity
5 height of the pressure pad
6 measuring line (electric cable or twin hydraulic tubing)
7 control and readout unit
8 medium investigated

Figure 1 — Principal components of a TPC measuring system

3.2
embedment pressure cell
total pressure cell which is fully embedded within a medium

EXAMPLE Push-in cell in soft soil; embedment cell in fill, “tangential cell” (see 3.10) in shotcrete tunnel lining.

3.3
contact pressure cell
total pressure cell which is placed in the contact plane between two media

EXAMPLE Cell at the base of a slab foundation; “radial cell” (see 3.9) in shotcrete tunnel lining.

3.4
borehole pressure cell
total pressure cell which is installed in a borehole

Note 1 to entry: See 2 in Figure 2.

3.5
aspect ratio
height to the smallest lateral dimension ratio of the pressure pad.

Note 1 to entry: For rectangular pads, the smallest lateral dimension is the width, for circular pads the diameter.

Note 2 to entry: Typical aspect ratios are of the order of 1:20 to 1:40.

3.6
total stress state
state of the ground where the internal forces acting in the ground are carried by the solid portion (skeleton) of the ground and the pore water

Note 1 to entry: One only stress component can be monitored by a total pressure cell (which is the change of the total normal stress $\Delta\sigma_n$; see 3.1).

Note 2 to entry: Changes of 2-D and 3-D stress states can be monitored by a cluster of a sufficient number of independently oriented TPCs installed at a measuring location: Three (3) TPCs for a 2-D stress state, and six (6) TPCs for a 3-D stress state.

Note 3 to entry: By placing a TPC pad with its sensing side towards the vertical, the vertical normal stress component σ_v can be directly monitored.

3.7
effective stress state
state of the ground where the internal forces acting in the ground are carried by the solid portion (skeleton) of the ground

Note 1 to entry: It is $\{\sigma'\} = \{\sigma\} - u$

where

$\{\sigma'\}$ = effective stress tensor;

$\{\sigma\}$ = total stress tensor;

u = porewater pressure.

3.8
contact stress
stress component which acts normal to a contact plane

EXAMPLE Normal stress acting in the interface between a slab foundation and the ground.

Note 1 to entry: Shear stresses acting within the contact plane cannot be measured by a TPC.

3.9
radial stress
specific contact stress between the ground and a tunnel lining

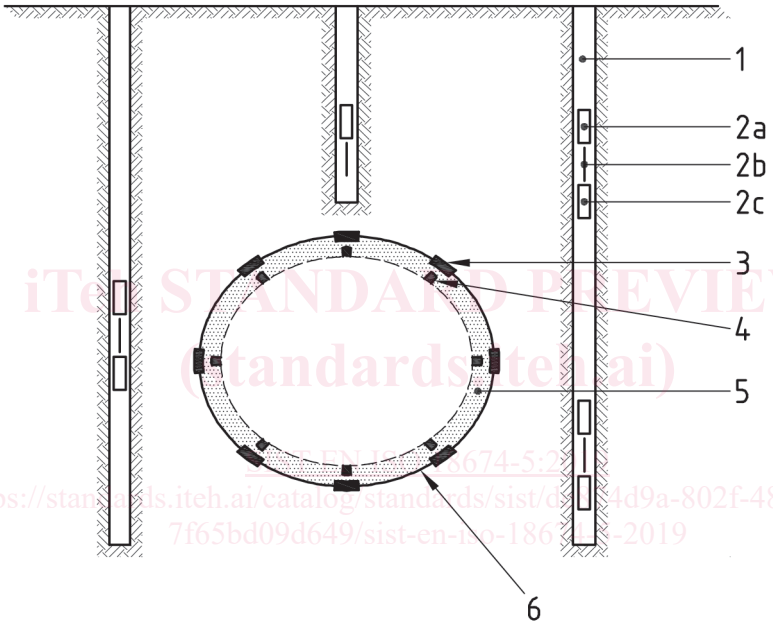
Note 1 to entry: Radial TPCs ("radial cells") are especially designed for monitoring radial stresses.

Note 2 to entry: See 3 in Figure 2.

3.10
tangential stress
hoop stress monitored within shotcrete or concrete tunnel linings

Note 1 to entry: Tangential TPCs ("tangential cells") are especially designed for monitoring tangential stresses in tunnel linings. An alternative term is "concrete TPC".

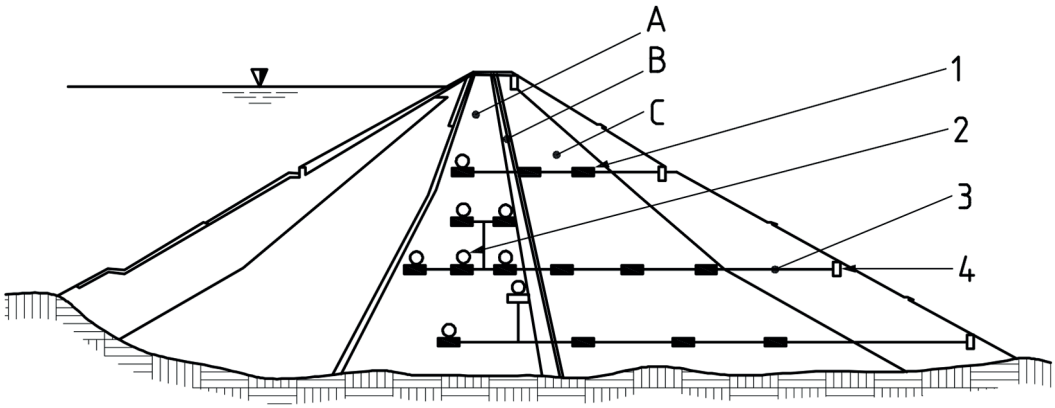
Note 2 to entry: See 4 in Figure 2.



Key

1 Borehole (vertically down-dipping; back-filled).
2 Array of three differently oriented borehole TPCs for monitoring horizontal ground stresses.
3 Radial TPCs at the ground/shotcrete lining interface.
4 Tangential TPCs in the shotcrete lining.
5 shotcrete lining
6 tunnel excavation contour

Figure 2 — Example of TPC layout in near-surface tunnelling



Key

A clay core
B filter zone
C rock fill
1 TPC (single or cluster)
2 piezometer
3 routing for measuring cable
4 terminal

Figure 3 — Example (schematic) of a TPC layout in an earth dam

4 Symbols

Symbol	Name	Unit
C	TPC edge correction factor	-
E	Young's modulus	MPa
p_a	pressure in the outer chamber of the measuring device	MPa
p_h	hydrostatic pressure difference between the external measuring station and TPC	MPa
p_L	pressure loss in measuring tube	MPa
$p_{p\text{-}t}$	pre-tensioning pressure	MPa
p_i	pressure in the inner chamber of the measuring device	MPa
p_F	pressure in a follow-up measurement	MPa
p_R	pressure in reference measurement	MPa
γ_{fluid}	specific weight of compensation fluid	N/m^3
σ_n σ_n'	normal stress (total; effective)	MPa
$\Delta\sigma_n$	difference of total normal stress	MPa
σ_v	vertical stress	MPa
σ_H	maximum horizontal stress	MPa
σ_h	minimum horizontal stress	MPa

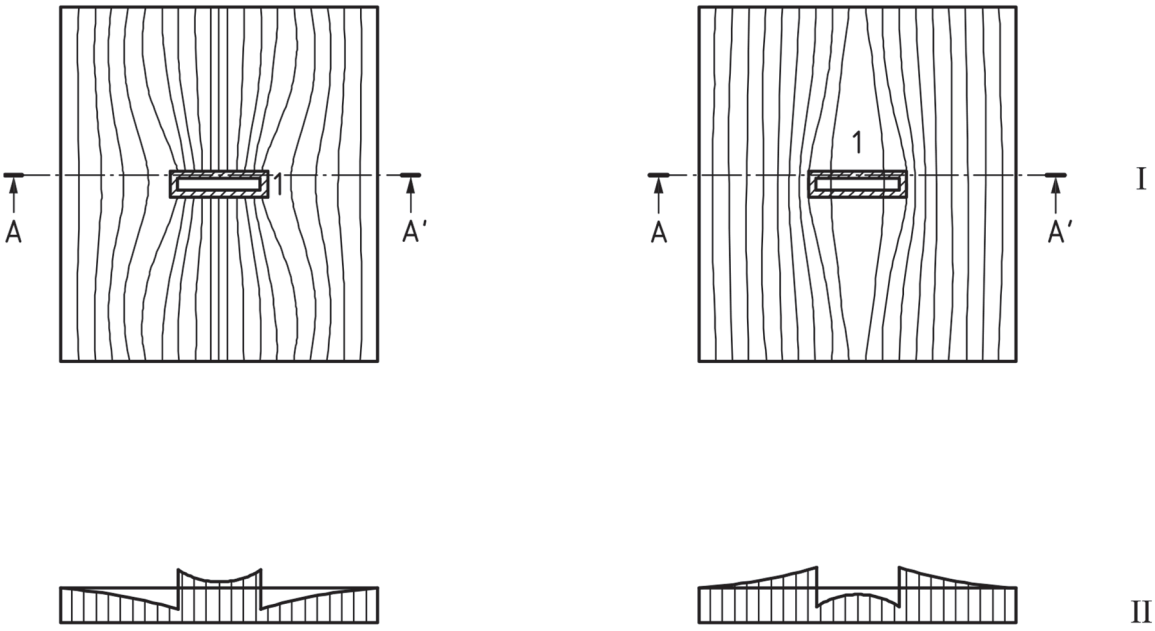
5 Instruments

5.1 General

5.1.1 It shall be noted that TPC measurements are prone to substantial errors as the presence of the cell in the medium tends to create significant changes in the stress field which is the target of the measurement.

NOTE 1 See Figure 4 (Reference [5]).

NOTE 2 The selection of appropriate instruments, adherence to their range of application and adequate installation procedures are critical to reduce these errors to acceptable levels (see 5.4 and 5.6).



a) TPC stiffer than medium (over-registering TPC)

b) TPC softer than medium (under-registering TPC)

Key

I Stress trajectories around a TPC

II Normal stress profile A — A'

1 Total pressure cell embedded in a medium.

Figure 4 — Registering effect of embedded TPCs

5.1.2 Deformation and compensation measuring methods should be distinguished from each other (see Table 1).

Table 1 — Monitoring features associated with TPC measuring methods

Measuring method	TPC stiffness	Long-term stability of sensor signal	Atmospheric pressure compensation	Automatic data acquisition	Logging speed
Deformation (see 5.2)	tends to be soft	depends, amongst others, on the type of electrical sensors used	independent barometric pressure monitoring may be needed vented TPC tend to be unreliable	amenable	comparatively quick
Compensation (see 5.3)	tends to be stiff	tends to be long-term stable	vented TPC tend to be reliable	cumbersome; comparatively costly	comparatively slow

5.1.3 Any change of the total normal stress $\Delta\sigma_n$ acting onto the flat side of a pressure pad (1 in Figure 1) shall be uniquely associated with a change of the pressure of the liquid in the intervening cavity of the TPC.

