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Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 8:
Measurement of loads: Load cells

Reconnaissance et essais géotechniques — Surveillance géotechnique par instrumentation in situ —

Partie 8: Mesure de charges: Cellules de charge

Reference number
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Foreword

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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 18674 series can be found on the ISO website.

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Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 8: Measurement of loads: Load cells

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document specifies the measurement of forces by means of load cells carried out for geotechnical monitoring. 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.

This document is applicable to:

— performance monitoring of geotechnical structures such as anchors, tiebacks, piles, struts, props and steel linings;

— checking geotechnical designs and adjustment of construction in connection with the observational method;

— evaluating stability during or after construction.

This document is not applicable to devices where the load is purposely applied to geotechnical structures in the wake of geotechnical field tests such as calibrated hydraulic jacks for pull-out tests of anchors or load tests of piles.

NOTE 1 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 load cells as part of the geotechnical investigation and testing in accordance with References [2] and [3].

NOTE 2 ISO 18674-7 is intended to define the measurement of forces by means of strain or displacement gauges.

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 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

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

3 Terms and definitions

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

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

3.1
load cell
field instrument for monitoring forces acting in geotechnical structures

Note 1 to entry: Load cells are commonly placed at an end of a structural member where forces are transmitted from one member to another.

EXAMPLE Load cell at the anchor head where the force acting in the anchor tendon is transmitted to a retaining wall.

Note 2 to entry: Common load cells are electric (see 3.2) and hydraulic (see 3.3) measuring principles.

Note 3 to entry: Indispensable components of load cells are a load bearing element and load distribution plates for transmitting forces between structural members.

Note 4 to entry: Load cells are not useful for fully grouted rock bolts.

3.2
electric load cell
instrument with an elastically-behaving body which deforms under the applied force, where the resulting deformation is measured by electric sensors

Note 1 to entry: An example of such body is a steel cylinder (see Figure 2).

Note 2 to entry: For typical electric sensors, see 5.2.4.

3.3
hydraulic load cell
instrument with a flat liquid-filled compartment where the force to be monitored acts normal to the flat distribution plates on the sides of the compartment and where the pressure in the liquid of the compartment is measured by a pressure measuring device

Note 1 to entry: See Figure 3.

Note 2 to entry: The compartment is formed by two steel plates, welded together around their peripheries, where the intervening cavity is filled with a liquid (de-gassed fluid).

3.4
anchor load cell
purpose-designed load cell with a centric passage to accommodate the anchor tendon

Note 1 to entry: See Figure 4.

Note 2 to entry: The tendon typically comprises a bar, strands or wires.

3.5
nominal range
range over which the load cell is calibrated

Note 1 to entry: Other terms which are used in practice are, for example, load range, nominal load, capacity, full-scale capacity or measuring range.

Note 2 to entry: Outside of the nominal range, the load cell is not calibrated and therefore the measurements are not reliable.

3.6
over range
maximum load that can be applied on the load cell, without damaging the load cell

Note 1 to entry: Other terms which are used in practice are, for example, “overrange capacity” or “overload”.

4 Symbols and abbreviated terms

Symbol	Name	Unit
B	smallest dimension in cross section of structural member	m
D_o	outer diameter	m
F	axial force acting in a member	N
FS	full scale	-
H	height	m
P_a	installation load	N
P_e	effective axial load	N
F_R	reaction force in the anchor head	N
P	axial load	N
R_T	pile toe resistance	N
T	temperature	°C
t	elapsed time	s, min, h, d
z	depth	m
α	angle between the tendon at the anchor head and the anchor axis	degree

5 Instruments

5.1 General

5.1.1 A load cell can be either electric (see 5.2) or hydraulic (see 5.3).

NOTE Other types of load cells, such as mechanical or photo-elastic are not considered in this document.

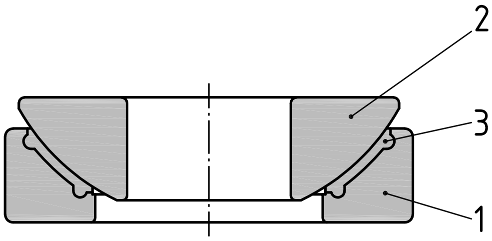
5.1.2 The maximum load anticipated in the lifetime of the monitoring project plus a margin of 10 % to 30 % shall not exceed the nominal range of the load cell after installation (see 6.1.1.7).

NOTE 1 Too large a margin reduces the accuracy of the measurements.

NOTE 2 The measurement in the lower end (5 % to 10 %) of the nominal range is often less accurate.

5.1.3 At the measuring location, the force acting in a structural member shall be transmitted through the load cell via load distribution plates. Spherical distribution plates may be used to improve an aligned load distribution.

NOTE See Figure 1 for an example of a spherical distribution plate.



Key

1 concave plate

2 convex plate

3 PTFE fabric

Figure 1 — Spherical load distribution plate (example)

5.1.4 The load cell shall have a specified load bearing element.

EXAMPLE See 1 in Figure 2 and 2 to 4 in Figure 3.

5.1.5 The material of the load bearing element (e.g. 1 in Figure 2) of the cell should be mechanically stable.

EXAMPLE Heat-treated steel grade S355J2+N according to Reference [4].

5.1.6 The influence of temperature on the load measurement shall be considered and documented. Exposure of the load cell to direct sunlight or other heat sources should be avoided or minimised. The load cells should be designed to minimize temperature errors.

NOTE 1 The readings of load cells are affected by temperature changes. The use of temperature-compensated sensors decreases the influence of temperature changes on the measurements. Information for temperature correction of the load cell are commonly provided by the manufacturer.

NOTE 2 Independent temperature measurements in the vicinity of the load cell assist in the evaluation of the load measuring results.

NOTE 3 Temperature changes can also affect the loads within the structural members, see ISO 18674-1:2015, 5.3.1.

5.2 Electric load cells

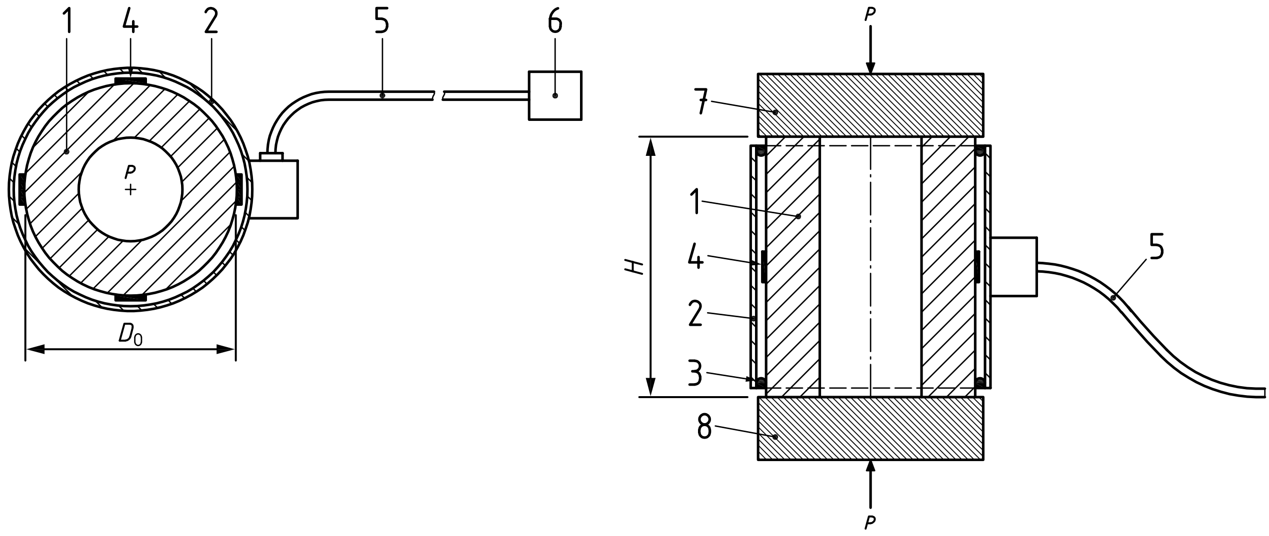
5.2.1 Electric load cells should have features as shown in Figure 2.

NOTE The load bearing element is usually either a solid cylinder or a hollow cylinder, see 1 in Figure 2.

5.2.2 Cylindrical load bearing elements should have a height H to outer diameter D_o ratio within the range of $0{,}1 \leq H/D_o \leq 2$.

NOTE 1 $H/D_o > 2$ tends to decrease the stability of the load cell assembly.

NOTE 2 The quality of the measurements of load cells with low ratios of H/D_o can be more sensitive to imperfections on alignment, placement and load distribution plates.



a) Top view

b) Side view

Key

D_o	outer diameter of load bearing element (1)	3	O-ring
P	load	4	electric sensor (here: full-bridge strain gauges)
H	height of load bearing element (1)	5	electric cable
1	load bearing element (here: hollow cylinder)	6	control and readout unit
2	protective cylindrical cover	7	upper load distribution plate
		8	lower load distribution plate

Figure 2 — Features of an electric load cell (example, see Reference [5])

5.2.3 The deformation of the load bearing element shall be measured by electrical sensors.

5.2.4 The sensor can be based on either strain gauge, piezo-electric, vibrating wire or capacitive measuring principles, configured in such a way that the influence of eccentric loading is minimised.

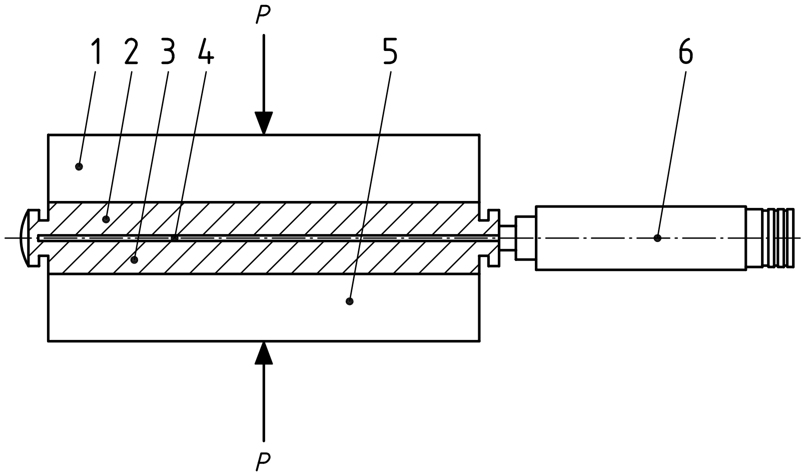
NOTE 1 The influence of eccentric loading can be typically minimised by using multiple sensors spaced evenly around the cylinder and at equal distance from the axis.

NOTE 2 The output signal of an electrical strain gauge load cell can depend on the power supply of the logging device, when not properly designed.

5.3 Hydraulic load cells

5.3.1 Hydraulic load cells should have features as shown in Figure 3.

NOTE Elements 2, 3 and 4 of Figure 3 form a liquid-filled compartment. Any change in the magnitude of the load *P* results in a change of the pressure of the liquid in the compartment (4 in Figure 3).



Key

P load
1 upper load distribution plate
2/3 load cell plates
4 liquid-filled compartment
5 lower load distribution plate/bearing plate
6 pressure measuring unit (here: electric pressure transducer)

Figure 3 — Features of a hydraulic load cell

5.3.2 The pressure measuring unit (6 in Figure 3) should be positioned as close as practically feasible to the liquid-filled compartment.

NOTE An increased spacing between the liquid-filled compartment (4) and the pressure measuring unit (6) results in a decreased stiffness of the load measuring system influencing the measurement.

5.3.3 The pressure measuring unit can be either a Bourdon gauge or an electric pressure transducer.

5.4 Instruments for specific applications

NOTE See Annex A.

5.4.1 Anchor load cells

5.4.1.1 Anchor load cells shall have an axial centric passage to accommodate the anchor tendon.

NOTE See Figures 1 and 4.

5.4.1.2 Anchor load cells can be of an electric (see 5.2) or hydraulic type (see 5.3).

5.4.1.3 At the measuring location, the anchor load shall be transmitted through the load cell via load distribution plates. The load distribution plates shall be designed to withstand yielding at capacity load and to limit distortions when distributing the load to the structure.

NOTE 1 See 7 and 8 in Figure 2 and 1 and 5 in Figure 3.

NOTE 2 Common are heat-treated steel load distribution plates of a H/D_o-ratio of about 0,22 to 0,30.

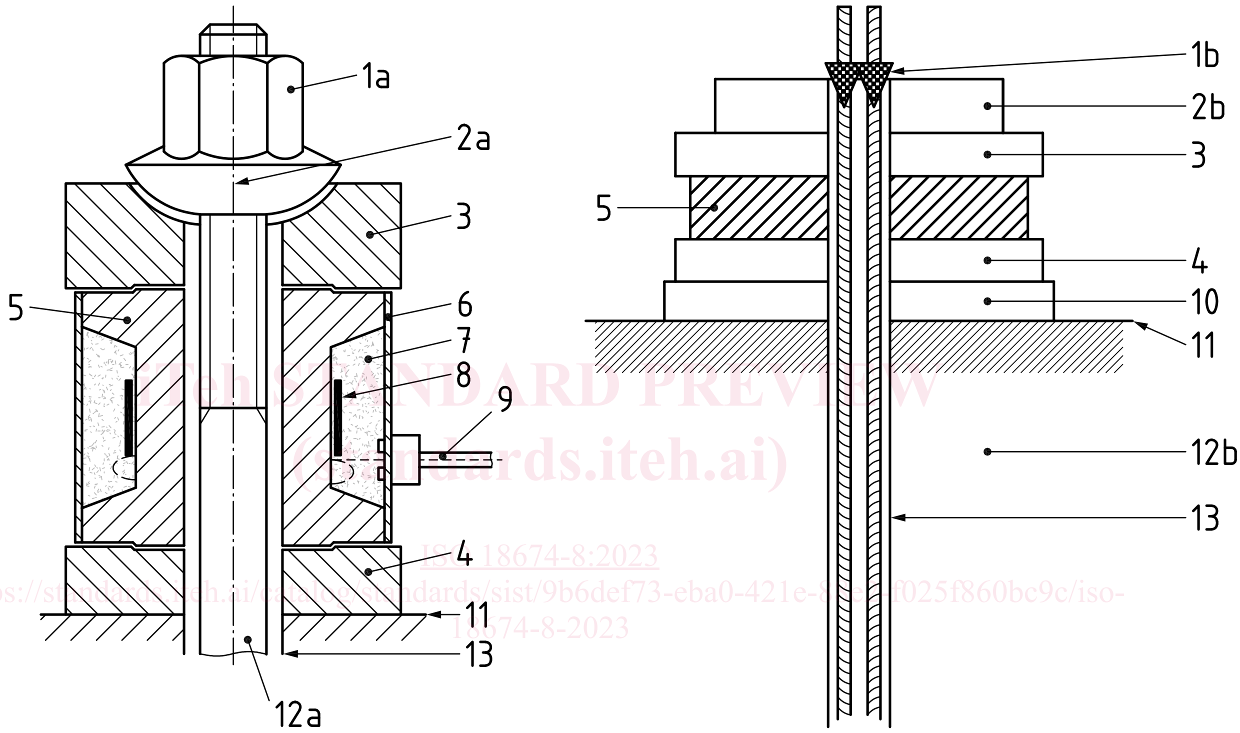
NOTE 3 The plate between the bearing element and the load cell (8 in Figure 2 and 5 in Figure 3) is commonly referred to as bearing plate.

5.4.1.4 The hole for feeding the anchor tendon through a load distribution plate shall be in the centre of the plate.

5.4.1.5 For anchor tendons, spherical seats or wedges may be used to improve aligned load distribution.

NOTE 1 See Figures 4 a) and b).

NOTE 2 Deviations from the perpendicular alignment between the load distribution plates and the anchor tendon generate a force component which acts in transverse direction of the load cell. This effect, which affects the accuracy of the anchor load measurement, cannot be avoided by a spherical nut or wedges, see 6.1.1.4 to 6.1.1.6.



a) Spherical seat for a bar tendon **b) Wedges for two strand tendons**

Key

1a	nut	5	load bearing element	10	bearing plate
1b	wedge	6	protection sleeve	11	ground surface
2a	spherical seat	7	potting	12a	bar tendon
2b	head plate	8	electric sensor	12b	strand tendon
3	upper load distribution plate	9	electric cable to readout	13	borehole wall
4	lower load distribution plate				

Figure 4 — Schematic layout of anchor head devices for aligning different types of tendons

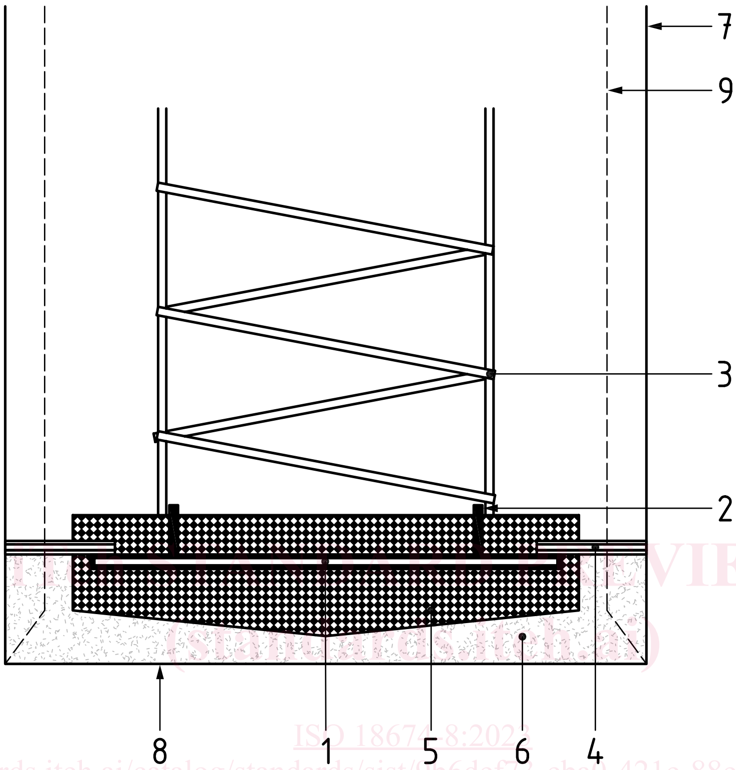
5.4.2 Load cell for cast-in-place concrete piles

5.4.2.1 When monitoring the performance of a cast-in-place concrete pile, a load cell may be located at the toe of the pile. In this case, the layout of the load cell should be as in Figure 5.

NOTE 1 The load at the top of the pile is commonly measured by means of strain gauges, see Reference [1].

NOTE 2 A load cell at the head or at another location between toe and head is commonly associated with pile testing procedures where a load is actively applied and systematically varied and where the deformational response of the pile is considered in dependency of the applied load.

NOTE 3 Outside of pile testing, the use of a load cell at the head of the pile is limited to situations where only axial loads are expected during the lifetime of the pile, as the presence of the load cell can influence the load transfer to the pile.



Key

1 hydraulic load cell embedded in (5)
2 weld ring
3 reinforcement cage
4 ring of compressible material (e.g. synthetic rubber)
5 conical plug (e.g. mortar)
6 concrete/mortar bed
7 borehole wall
8 bottom of borehole
9 casing inner wall (where applicable)

Figure 5 — Schematic layout of a hydraulic load cell at the base of a cast-in-place concrete pile (example, see Reference [6])

5.4.2.2 In case of a pile diameter greater than 1,00 m, an array of at least three load cells can be used. Number and position (layout/geometry) of the load cells shall be designed to minimize eccentricity. Distribution plates shall be designed to equally distribute the load into the load cells.

