SLOVENSKI STANDARD
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Geotechnical investigation and testing - Geotechnical monitoring by field instrumentation - Part 7: Measurement of strains: Strain gauges (ISO/DIS 18674-7:2024)

Geotechnische Erkundung und Untersuchung - Geotechnische Messungen - Teil 7: Dehnungsmesszellen (ISO/DIS 18674-7:2024)

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Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 7:
Measurement of strains: Strain gauges

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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/TC182, *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 7: Measurement of strains: Strain gauges

1 Scope

This document specifies the measurement of strain by means of strain gauges and strainmeters 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 18674-1:2015.

This document is applicable to:

— performance monitoring of

  — 1-D structural members such as piles, struts, props and anchor tendons;

  — 2-D structural members such as foundation plates, sheet piles, diaphragm walls, retaining walls and shotcrete/concrete tunnel linings;

  — 3-D structural members such as gravity dams, earth- and rock-fill dams, embankments and reinforced soil structures

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

— evaluating stability during or after construction.

With the aid of a stress-strain relationship of the material, strain data may be converted into stress and/or forces (for 1-D members; see ISO 18674-8:2022) or stresses (for 2-D and 3-D members, see ISO 18674-5:2019).

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 strain measuring instruments as part of the geotechnical investigation and testing in accordance with References [1] and [2].

2 Normative references

The following documents, in whole or in parts, are normatively referenced in this document and are indispensable for its application. 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 18674-2:2016, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 2: Measurement of displacements along a line: Extensometers*

ISO 18674-3:2017, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 3: Measurement of displacements across a line: Inclinometers*

ISO 18674-4:2020, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 4: Measurement of pore water pressure: Piezometers*

ISO 18674-5:2019, *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation — Part 5: Stress change measurements by total pressure cells (TPC)*

ISO 18674-8:2022, *Geotechnical investigation and testing – Geotechnical monitoring by field instrumentation – Part 8: Measurements of loads: Load Cells*

3 Terms and definitions

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

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 https://www.electropedia.org/

3.1
strain gauge
field instrument for measuring strain in structural members

Note 1 to entry: The strain is sensed over the full length of the gauge, commonly by a vibrating wire sensor, an electrical resistance strain gauge sensor or an FBG sensor (Fibre Bragg Gratings with optical sensing).

Note 2 to entry: Typical configurations are strain gauges mounted to a surface of a steel member (see 3.3 and Figures 1a,1b, 3a,3b), strain gauges embedded in concrete (see 3.4 and Figure 1c) or FBG integrated into the structure or fixed onto the surface (see Figure 3b).

Note 3 to entry: A series of FBG sensors with a single lead cable is named FBG array (see Figure 4).

Note 4 to entry: For mechanical strain gauges, see Reference [3].

Note 5 to entry: Distributed fibre optic strain measurements (DFOS) are not subject to this standard, as this new technology still is under intensive development and change. Usage principles and examples for DFOS are given in the Annex B (informative)

3.2
strainmeter
strain gauge for measuring strain by means of a displacement measurement

Note 1 to entry: The strain is sensed over the defined gauge length of the strainmeter (see Figure 2)

Note 2 to entry: An extensometer with a defined gauge length, e.g. a mobile extensometer (see ISO 18674-2:2016) has the function of a strainmeter

Note 3 to entry: A typical configuration is a continuous chain of strainmeters embedded in fill, soil or concrete.

Note 4 to entry: Alternative terms for a strainmeter used in practice are “fill extensometer”, “soil strainmeter”, “soil extensometer”, “embankment extensometer” or “linear continuous extensometer“

Note 5 to entry: The term strainmeter is sometimes (incorrectly) used for specific strain gauge sensors, e.g. rebar strainmeter

3.3
surface-mounted strain gauge
strain gauge designed for attachment at the surface of a structural member

Note 1 to entry: There are different types of instruments for surface-mounting: spot-weldable, arc welded and adhesive bonded strain gauges

3.4
embedment strain gauge
strain gauge for the embedment in a medium

Note 1 to entry: Typically, the medium is mortar, grout, reinforced concrete, shotcrete or mass concrete

Note 2 to entry: see Figure 1c.

3.5
instrumented reinforcement bar
Piece of reinforcement bar into which a strain gauge is integrated.

Note 1 to entry: when installed alongside the structural reinforcement it is commonly known as a sister bar

Note 2 to entry: when installed as part of the structural reinforcement it is commonly known as a rebar strain meter

Note 3 to entry: sister bars and rebars measure the same parameter, overall strain in a reinforced concrete element. Difference in using sister bars or rebars is that when using sister bars the overall steel area in the structural element increases slightly leading to a reduction of the actual strain at the measuring section.

Note 4 to entry: see Figure 5.

3.6
gauge length
initial length over which the strain is measured by the strain gauge or initial length over which the displacement is measured by a strainmeter

Note 1 to entry: For vibrating wire strain gauges and strainmeters the length is defined by the mounting blocks / end plates or anchors

Note 2 to entry: For a FBG strain gauge, depending on the mounting, the gauge length is either the length of the grating or the distance between the mounting blocks / end plates, anchors or spots of adhesive (see Figures 3 and 4)

Note 3 to entry: For instrumented reinforcement bars that are installed alongside the structural reinforcement, the gauge length is the length between the anchoring zone of the bar, which is difficult to define precisely.

4 Symbols

Symbol	Name	Unit
A	area	m^2
E	Young's modulus	Pa
F	normal force	N
L	gauge length	m
n	number of instruments	-
S	shear force	N
s	spacing between strain sensor and axis	m
T	temperature	°C
α_T	coefficient of linear thermal expansion	K^{-1}
ε	normal strain	-
$\mu\varepsilon$	micro strain	µm/m
σ	normal stress	Pa
$2a$	height of I-Beam	m
$2b$	width of I-Beam	m
c	distance to XX-axis	m

Symbol	Name	Unit
D	Diameter	m
d	Distance to YY-axis	m
t	Thickness	m
XX	x-axis	-
YY	y-axis	-

Subscripts		
ax	axial in relation to compression (sign +) / extension (sign -) of a 1-D member	-
ax'	axial in relation to bending of a 1-D member	-
corr	corrected value	-
F	follow-up value	-
G	gauge instrument	-
i	measuring point i	-
R	reference value	-
T	temperature, thermal	-

5 Instruments

5.1 General

5.1.1 Distinctions should be made between

(a) the type of the strain measuring instrument (strain gauge type versus strainmeter), and

(b) the location of the measuring point (at the surface of a structural member versus embedded in a medium).

(c) the measurement principle of the instrument (e.g. VW, electrical resistance or FBG)

NOTE See Table 1 and Figures 1 to 5.

Table 1 — Types of strain gauges and strainmeters in geotechnical monitoring

Strain measuring instrument and common configuration	Location of measuring point	Member / medium	Common gauge length [mm]	Common sensor	Section
surface-mounted strain gauge	at the surface of a structural member	steel (1)	5 – 150	vibrating wire (VW) or electrical resistance strain gauges, FBG	5.2.1
		concrete (2)	50 – 350		
embedment strain gauge	inside medium	concrete (3)	50 –500		5.2.2
strainmeter		fill (4)	1 000 – 3 000	Displacement transducer	5.3

EXAMPLES (1) reinforcing bar, steel pile, sheet pile, strut
(2) pillars, girder, beam
(3) concrete pile, diaphragm wall, gravity dam, shotcrete tunnel lining
(4) earth dam, rock-fill dam, embankment

5.1.2 In line with the geotechnical engineering sign convention, compressive strain should be taken as positive.

NOTE 1 Within the ISO 18674 series, that sign convention is adopted in Part 4 (piezometers), Part 5 (total pressure cells) and Part 8 (load cells), however not in Part 2 (extensometers). The latter adopts the sign convention established in geodesy.

NOTE 2 In ISO 18674-1:2015, no unified rules were set on the sign convention for geotechnical monitoring instrumentations. In Clause 5.1.2 it is stated in general terms that "the sign conventions and units shall be clearly stated and adhered to".

5.1.3 The instrument shall be selected such that it has negligible influence on the elastic stiffness of the monitored structure.

5.1.4 The measuring range of the instrument shall be selected according to the expected strain range within the project. The measuring range of the instrument shall be 25 % higher than the expected strain in the member to measure.

NOTE Many types of vibrating wire strain gauges and strainmeters allow the adjusting of the range starting point towards tension or compression.

5.1.5 If the stiffness of the medium is changing in time, e.g. in course of curing or consolidation of the medium, an instrument should be selected which is designed for a low stiffness in the strain measuring direction.

5.1.6 For an instrument installed in respectively on matrix or composite material, sturdiness and the gauge length of the strain instrument shall be selected considering the size of the aggregates in the medium. If possible, the ratio of the gauge length to the largest aggregate should be more than 5 or 6.

5.1.7 Strain instruments shall not be located at or near the ends of a structural member or connection points with other structural members in order to measure homogenous strain. A distance of at least three times the width, respectively the diameter, of the member can be considered as sufficient.

5.1.8 The temperature shall be monitored at the measurement point or at a representative location.

NOTE Commercially available vibrating wire strain gauge and FBG sensors have integrated temperature sensors.

5.1.9 Temperature effects on the instrument as well as on the structure itself shall be taken into account when reporting and analysing the data.

NOTE 1 Temperature effects on the stresses in the structural members is often large and insufficiently known, see Annex C

NOTE 2 The use of strain gauges compensated for specific materials (steel, aluminium, concrete) avoids the need to correct the measured strain to obtain the structural strain and calculate the stress.

5.1.10 When FBG sensors are used in series, FBG shall be manufactured with different Bragg wavelengths.

NOTE The number of FBG that can be in series will depend the FBG interrogator as well as the amount of strain to be measured.

5.2 Strain gauges

5.2.1 Surface-mounted strain gauges

5.2.1.1 The fixing and the type of strain gauge should be selected depending on the surface onto which it is to be mounted.

NOTE 1 Spot-welded gauges (see Figure 1a) commonly are applied to rebars, arc-welded gauges (see Figure 1b) to larger steel members such as struts, steel sets or sheet piles.

NOTE 2 The advantages of the spot-welded gauge are its small size and minimum errors that result from bending of the member due to the close proximity of the strain gauge to the surface of the member.

NOTE 3 If adequate space is available on a steel surface, an arc-welded version is commonly preferred, see Reference [4].

NOTE 4 Adhesive bonding is commonly applied on compound material or for FBG sensors on steel. FBG strain arrays are sometimes bonded into pre-manufactured grooves of steel members for better protection.

NOTE 5 Strain gauges based on the electrical resistance principle (foils sensors) are commonly applied with adhesive bonding to a surface.

5.2.1.2 When arc-welding is applied, a dummy rod should be used as a spacer whilst the mounting blocks are welded (see 1 in Figure 1b). After welding, the dummy rod can be replaced by the strain gauge sensor (see 2,3 and 4 in Figure 1b).

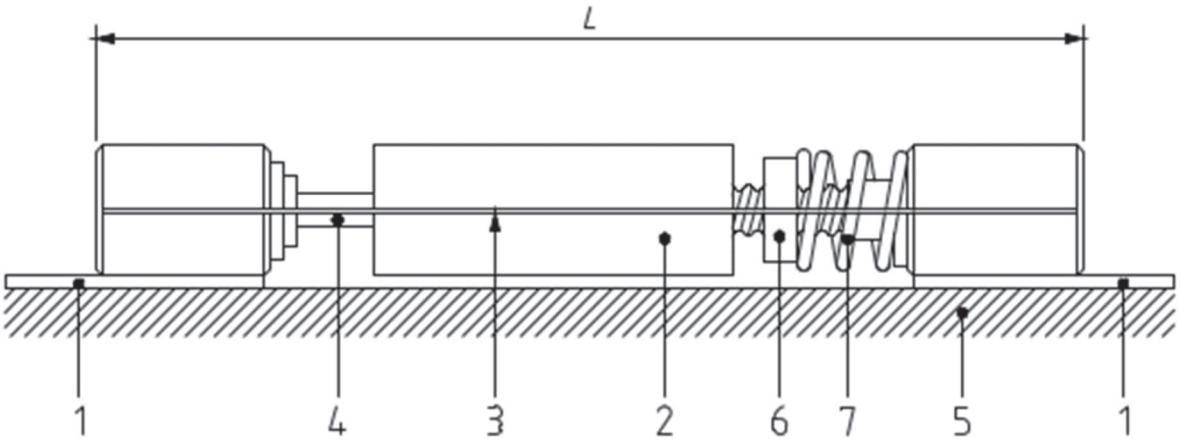
NOTE This procedure is carried out to shield the sensitive strain sensor from arc-welding effects.

5.2.1.3 When mounting blocks are used, these can have set screws acting in different directions.

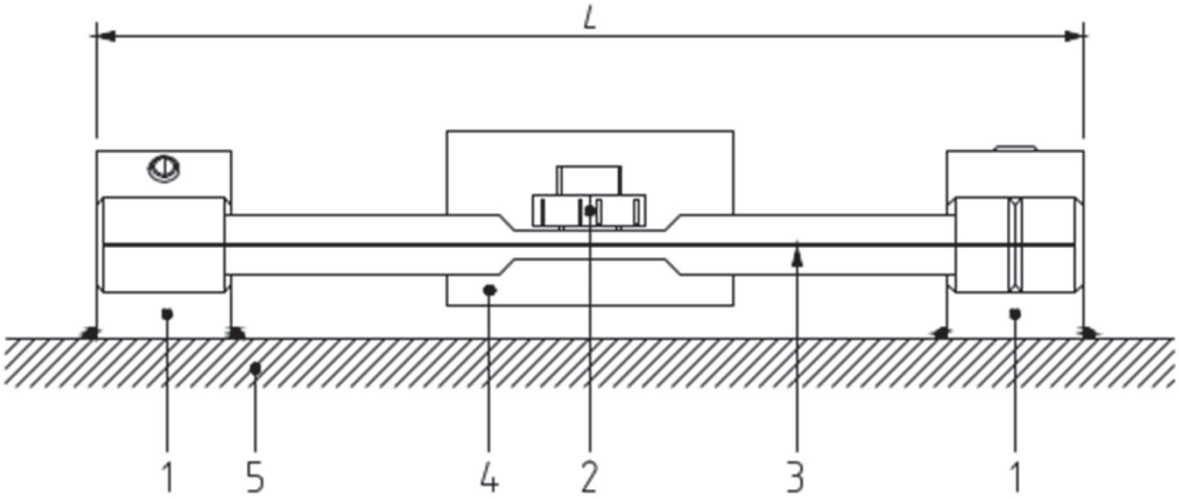
NOTE 1 See Figures 1b and 12.

NOTE 2 For examples with mounting blocks see Figures 3c, 3d and Figure 4a.

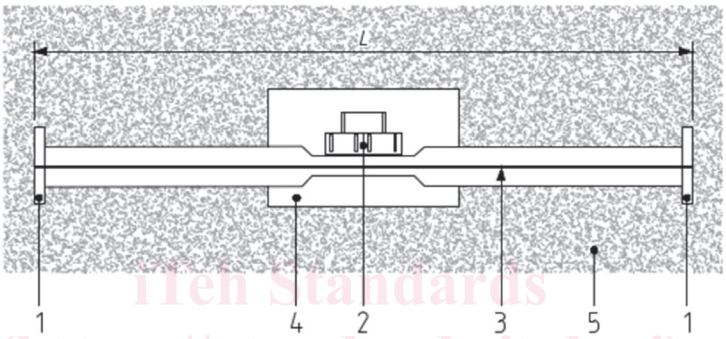
5.2.1.4 For gauge length installation of FBG strain arrays and FBG strain gauges, the cable / sensor shall be pre-tensioned. The pretension level shall consider the strain to be measured.



a) spot-weldable strain gauge



b) arc-weldable strain gauge

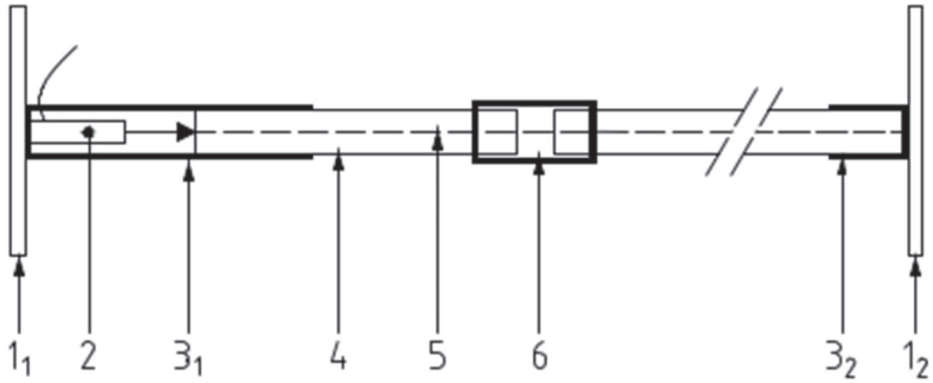


c) embedment strain gauge

Key

1	anchor/flange, mounting block/tab	2	plucking coil
3	steel vibrating wire	4	protection housing
5	substrate/medium (e.g. steel/concrete)	6	screw nut on setting screw
7	spring		

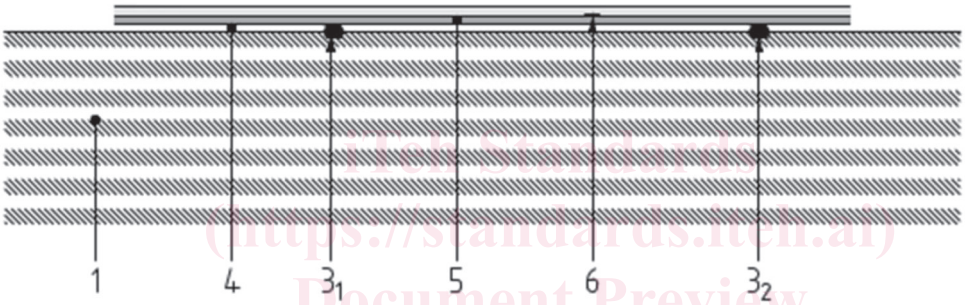
Figure 1 — Features of vibrating wire strain gauges



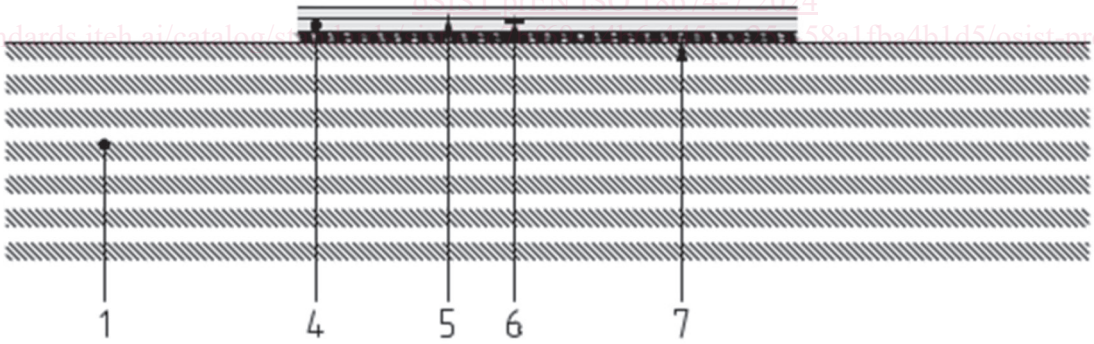
Key

$1_{1,2}$	anchors (here illustrated as flanges)	4	telescopic tube
2	displacement transducer with electric cable	5	extension rod
$3_{1,2}$	guides	6	sleeve

Figure 2 — Features of a strainmeter



a) spot-weldable FBG strain gauge



b) epoxy bonded FBG strain gauge