INTERNATIONAL STANDARD

ISO 18674-1

First edition
2015-05-15

Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 1: General rules

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

Partie 1: Règles générales

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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 WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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ISO 18674-1 was prepared by European Committee for Standardization (CEN) in collaboration with ISO/TC 182, *Geotechnics*, Subcommittee SC 01, *Geotechnical investigation and testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 18674 consists of the following parts, under the general title *Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation:*

— *Part 1: General rules*

The following parts are under preparation:

— *Part 2: Displacement measurements along a line: Extensometers*

The following parts are planned:

— *Part 3: Displacement measurements across a line: Inclinometers*

— *Part 4: Piezometers*

— *Part 5: Total pressure cells*

— *Part 6: Hydraulic settlement gauges*

— *Part 7: Strain gauges*

— *Part 8: Load cells*

— *Part 9: Geodetic monitoring instruments*

— *Part 10: Vibration monitoring instruments*

NOTE For further information on geotechnical monitoring by field instrumentation, see References [1] to [7].

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Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 1: General rules

1 Scope

This part of ISO 18674 lays out the general rules for the performance monitoring of the ground, of structures interacting with the ground, of geotechnical fills, and of geotechnical works.

NOTE ISO 18674 fulfils the requirements for general rules for the performance monitoring of the ground, of structures interacting with the ground, of geotechnical fills, and of geotechnical works as part of the geotechnical investigation and testing according to EN 1997-1[8] and EN 1997-2[9].

Specifically, this part of ISO 18674 applies to field instrumentation and measurements carried out

— in connection with site investigations of soils and rocks,

— in connection with Observational Design procedures,

— in connection with the performance of geotechnical structures before, during, and after construction,

— for ground behaviour evaluation, e.g. unstable slopes, consolidation etc.,

— for the proof or follow-up of a new equilibrium within the ground, after disturbance of its natural state by construction measures (e.g. foundation loads, excavation of soil, tunnelling),

— for the proof or follow-up of the stability, serviceability, and safety of structures and operations which might be influenced by geotechnical construction,

— for perpetuation of evidence, and

— for the evaluation and control of geotechnical works.

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2 Normative references

The following documents, in whole or in part, 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.

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

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 execution*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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3 Terms and symbols

3.1 Terms

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 99:2007 and the following apply.

3.1.1
geotechnical monitoring
observation of the ground behaviour and/or performance of geotechnical structures before, during, and/or after construction

Note 1 to entry: Geotechnical monitoring is an integral part of the Observational Design procedure (see EN 1997–1: 2004).

Note 2 to entry: Geotechnical monitoring is based on field observation, including construction site inspection.

3.1.2
field instrument
measuring tool to assist geotechnical monitoring

Note 1 to entry: Monitoring by field instruments comprises the measurement of physical parameters, in particular, the change of the parameter values.

3.1.3
geotechnical key parameter
physical parameter indicative of the geotechnical issue under consideration and subject to geotechnical monitoring

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EXAMPLE Displacement (absolute or relative), strain, inclination, stress, pore pressure, earth pressure, force, velocity, acceleration, temperature.

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3.1.4
geotechnical monitoring project
entirety of aspects and processes which, in a specific project, are relevant for geotechnical monitoring

Note 1 to entry: Includes planning, risk assessment, specifying, procurement, delivery, and installation of a project-specific monitoring system and collecting, processing, evaluating, and reporting of the monitoring data.

3.1.5
geotechnical monitoring concept
preliminary plan for the measurement of geotechnical key parameters developed within the conceptual design phase, identifying specific objectives such as risk mitigation to be addressed by monitoring, thereby considering type of measurement, measuring locations, and schedule(s) for carrying out the measurement

3.1.6
geotechnical monitoring plan
advancement of the monitoring concept within the specification design phase

3.1.7
geotechnical monitoring system
hardware and software to provide field data

Note 1 to entry: Includes instruments signal, transmission (e.g. electric cables), data acquisition, and auxiliary units.

Note 2 to entry: The performance (e.g. the accuracy, stability, precision) of the geotechnical monitoring system will not necessarily be identical to the performances of the system components.

3.1.8
geotechnical monitoring programme
entirety of those components of a monitoring project which can be systematically planned, consisting of a monitoring plan and monitoring system

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3.1.9
commissioning
demonstration and acceptance of the correct functioning of an installed monitoring system

Note 1 to entry: The commissioning criteria are commonly defined in the monitoring plan.

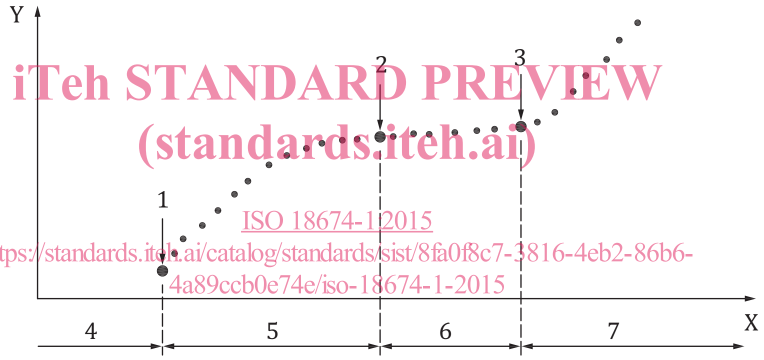
3.1.10
instrument data sheet
manufacturer's document containing instrument technical specifications

3.1.11
initial measurement
first measurement after installation (see Figure 1)

3.1.12
zero measurement
measurement carried out after stabilization of installation effects (see Figure 1)

Note 1 to entry: The zero measurement is often taken as reference for subsequent measurements, as it is commonly related to local space and time coordinates.

Note 2 to entry: The zero measurement is commonly carried out with increased measuring effort, e.g. repetition of measurements, to provide a reliable datum for subsequent measurements.



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Key

1 initial measurement
2 zero measurement
3 reference measurement
4 installation period
5 stabilization period
6 period of baseline measurements
7 construction period
X time
Y reading

Figure 1 — Definition of distinct measuring points during a geotechnical monitoring project in the period up to and including the construction phase

3.1.13
baseline measurements
measurements carried out, subsequent to the zero measurement, over a period of time before any construction starts, to help in the definition of changes that occur from causes other than construction

EXAMPLE Seasonal changes in groundwater levels, tidal and moisture content changes, climatic changes such as temperature, and incidence of sunlight.

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3.1.14
reference measurement
measurement which serves as reference base for previous and subsequent measurements

Note 1 to entry: The reference measurement is also known as datum measurement.

Note 2 to entry: A new reference measurement is often used for a new construction phase.

Note 3 to entry: The reference measurement is often derived from several measurements.

3.1.15
value change measurement
difference between a measurement and the reference measurement

3.1.16
point measurement
measurement of a physical parameter at a point

EXAMPLE Displacement of a measuring point; force of an anchor at its head; stress state in the ground; porewater pressure in an embankment; water discharge rate at the downstream toe of a dam.

3.1.17
line measurement
measurement of a physical parameter along a line

EXAMPLE Inclinometer measuring survey of a borehole.

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3.2 Symbols

For the purpose of this document, the symbols of Table 1 apply.

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Table 1 — Symbols

Symbol	Name	Unit
d	borehole diameter	m
i	number of measurement, measurement direction, or measuring point	-
l	distance	m
u, v, w	displacement component in x-, y-, z- direction, respectively	m
u	porewater pressure	Pa
x, y, z	local coordinates	m
z_w	piezometric level	m
α	angle, inclination	Degree or mm/m
ε_n	strain normal to measuring plane	-
$\varepsilon_x\ \varepsilon_y\ \varepsilon_z$	normal strain with reference to borehole coordinates	-
$\gamma_{xy}\ \gamma_{yz}\ \gamma_{zx}$	shear strain with reference to borehole coordinates	-
$\sigma_1\ \sigma_2\ \sigma_3$	principal stress	Pa
σ_n	normal stress with reference to measuring plane	Pa
$\sigma_x\ \sigma_y\ \sigma_z$	normal stress components with reference to borehole coordinates	Pa
$\tau_{xy}\ \tau_{yz}\ \tau_{zx}$	shear stress components with reference to borehole coordinates	Pa

NOTE Symbols with more than one meaning (e.g. u) are distinguishable in the context of their use.

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4 Principal requirements

4.1 Geotechnical monitoring in connection with geotechnical design

Geotechnical monitoring shall be designed, implemented, and evaluated in connection with the geotechnical design.

NOTE Figure C.1 shows the position of geotechnical monitoring in connection with the design and the construction of geotechnical structures; see also "observational method" in EN 1997–1: 2004, 2.7.

4.2 Geotechnical monitoring in connection with specific questions

Each geotechnical monitoring project shall be based on at least one specific question that is to be answered. The question shall be formulated at the start of the monitoring project and actualized throughout the project with the aid of information from the measurements.

NOTE Monitoring of construction procedures and long-term monitoring of existing safety-sensitive structures are included.

4.3 Requirements of a geotechnical monitoring project

4.3.1 In a geotechnical monitoring project, all items as defined in 3.1.4 shall be considered in the sequence described in 4.3.2 to 4.3.7.

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4.3.2 Within the initiation and preliminary design phase, reference shall be made to the geotechnical issue to be addressed. The key parameters shall be identified and their expected range estimated. The accuracy and the uncertainty with which the key parameters are to be measured and their geotechnically tolerable limits shall be specified.

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4.3.3 Within the conceptual design phase, a concept shall be developed on how to measure the key parameters of the geotechnical issue under consideration.

NOTE Aspects for consideration are the principal type of the instruments, frequency of measurements, redundancy in the system, the anticipated operation time of the monitoring system, and potential risks associated with monitoring.

4.3.4 Within the specification design phase, the monitoring concept shall be refined and transferred into a comprehensive monitoring programme. Aspects which shall be considered are the instrument selection based on instrument data sheets (Annex A) together with expected field performance and the specification of the instrument installation procedure.

NOTE 1 The monitoring plan includes the specification of the measuring procedure, the location of the monitoring points, the monitoring schedule, and the type of data collection (manual reading or data logging with or without remote data access).

NOTE 2 The measuring procedure might encompass the measuring principle (physical base of the measurement, e.g. vibrating wire principle) and of the measuring method (e.g. compensation method, digital/analogue method).

NOTE 3 Field instruments comprise a large variety of sensors with different measuring principles which all have their specific advantages and disadvantages depending on the type of application. Examples of sensors with different measuring principles are vibrating wire, current-loop, inductive, capacitive, resistance strain gauge, and fibre-optical sensors.

4.3.5 Within the installation and data collection phases, it shall be ensured that

— the instrument system is installed as early as possible prior to construction for baseline measurements (see Figure 1),

— the installation is carried out in such a way as to achieve good conformance of the measuring instruments,

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NOTE Good conformance is associated with only insignificant, if any, alterations of the measured values by the presence of the instrument

— the instruments are operated and handled in accordance with the manufacturer's instructions, and

— the monitoring system is routinely inspected and adequately protected from site works.

4.3.6 Within the data processing, evaluation, and reporting phase, attention shall be paid to the fact that the monitoring data are often affected by instrument, installation, and environmental effects (see 5.3). In the evaluation process, plausibility checks of the monitoring data shall be carried out. Checking shall include instrument, as well as geotechnical aspects (see 8.5).

4.3.7 The monitoring results shall be evaluated in respect to the geotechnical issue under consideration.

4.4 Geodetic measurements

For the support, evaluation, and control of geotechnical measurements, reference shall be made to geodetic measurements if applicable.

NOTE 1 See ISO 18674-9.

NOTE 2 For comparison of geotechnical and geodetic measurements, see Table C.1.

4.5 Safety requirements

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National and site safety regulations shall be followed.

EXAMPLES Regulations for:

— personal health and safety equipment;

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— clean air if working in confined spaces;

— ensuring the safety of the measuring system and its components.

5 Requirements of a geotechnical monitoring system

5.1 General

5.1.1 Geotechnical monitoring systems are subject to specific conditions, which shall be accounted for in the monitoring programme and evaluation of the monitoring data. These conditions include the following:

— mechanical, hydro-mechanical, or thermo-mechanical interaction between critical components of the geotechnical measuring system (e.g. sensors, measuring lines) and the surrounding medium in which the components are embedded;

— environmental conditions (e.g. aggressive groundwater and gases; high ground pressure; electro-magnetic disturbance) which might affect the embedded components;

— vulnerability of the data communication of the monitoring system (e.g. long measuring lines, often passing through construction zones).

5.1.2 The sign conventions and units shall be clearly stated and adhered to.

5.1.3 Requirements 5.2 to 5.6 shall be documented.

NOTE Manufacturers' documentation, e.g. instrument data sheets (see Annex A), is to provide a basis to make an informed choice of the instruments.

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5.2 Robustness

5.2.1 The components of the system shall be robust enough to effectively perform their individual functions over the design lifetime of the system, despite environmental and construction conditions.

NOTE This requirement relates to the material used (e.g. quality of the measuring cable, corrosion resistance of sensors), the type of construction of the installed units, and to the safety of the entire monitoring system, e.g. towards over-voltage (lightning protection), disturbance from the construction site, and vandalism.

5.2.2 Failure in data communication, e.g. of cables, radio links, is a potential problem. When planning geotechnical monitoring systems, these risks should be managed.

EXAMPLE In automatic monitoring systems, provision for communication failure alarms and low power levels.

5.2.3 Where damage is likely then, in addition to protection provisions, the need to replace or repair equipment should be anticipated. Provisions such as these shall be included in the monitoring plan.

5.3 Influencing factors

5.3.1 For the evaluation of geotechnical measurements, all relevant factors which influence the sensor signal shall be addressed. Conceptually, discrimination shall be made between direct and indirect influences onto the measured physical quantity.

NOTE 1 Direct influences are related to the object being monitored. Indirect influences are related to the monitoring system.

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NOTE 2 Common factors that can influence the monitoring system are changes of the temperature and atmospheric pressure.

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NOTE 3 The monitoring system might also be influenced by factors such as high voltage lines, electro-magnetic disturbance, and ground vibrations.

5.3.2 Provisions shall be made to discriminate between the respective effects of the influencing factors onto the monitoring object and monitoring system.

EXAMPLES Choice of temperature-compensated displacement transducer; pressure-compensated piezometer; extensometer rods with a material of low thermal expansion coefficient; provision of zero stress strain gauges; temperature correction of convergence tape measurements (see ISO 18674-2).

5.4 Redundancy

Geotechnical measurements should include redundancy to ensure the continued functioning of the system despite possible component malfunction. A redundancy in the measuring data should be used for the identification of erroneous readings and for data corrections.

EXAMPLES (in order of increasing degree of redundancy):

— multiple readings;

— installation of more sensors than theoretically required, e.g. more than 3 sensors in 2-D stress monitoring;

— duplication of sensors of the same measuring principle;

— application of different measuring principles for one and the same quantity (“diversification”).

5.5 Stability of sensor signal

As a re-calibration (see 5.6) of permanently embedded sensors is hardly possible, attention shall be given to the stability of the measuring signal of sensors and to the redundancy of the monitoring system.

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It should be ensured that the signal could be expected to be sufficiently stable over the time span of the monitoring project.

NOTE Safety-sensitive geotechnical structures such as tunnels and dams often require long-term monitoring.

5.6 Function check and calibration

Function checks and/or instrument calibrations shall be carried out and documented at the following stages of the monitoring project.

— Prior to shipment; these shall be the responsibility of the manufacturer and are to be documented in calibration certificates.

— Before installation (*pre-installation acceptance tests)*; these shall be documented in a certificate. If possible, this also includes checking of the zero point and scale of the system components.

— After installation (*post-installation acceptance tests)*.

NOTE Pre-installation and post-installation acceptance tests are part of the commissioning.

— During service life; the accessible components of the monitoring systems shall be re-calibrated at specified intervals. The interval between any two re-calibrations shall be addressed in the monitoring programme, considering also the recommendations of the manufacturer, the usage, and the environment. If possible, a calibration should be carried out if reasonable doubts exist on the reliability or accuracy of an instrument component. Additional re-calibrations may become necessary in specific measuring applications.

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NOTE See ISO 18674-2.

6 Location of measuring points and geotechnical parameters

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6.1 Location of measuring points

6.1.1 The measuring points can be located at free surfaces, at the interface between any two media, or inside of a medium.

6.1.2 Measuring points in the ground are to be installed in boreholes. The measurement of these points should be related to the local coordinates of the borehole under consideration (see Annex B).

NOTE 1 Boreholes provide the possibility to install sensors within the measuring object and allow the access to the measuring points.

NOTE 2 The term “borehole” implies other sub-surface installations, such as push-in installations, trial pits, shafts, and adits.

6.2 Measurement and monitoring of geotechnical parameters

6.2.1 Geotechnical monitoring shall be based on the measurement of geotechnical key parameters.

NOTE For examples of geotechnical key parameters and their measurement, see Table D.1 and Annex E.

6.2.2 Geotechnical monitoring measures values of a parameter from which changes can be determined by comparison to those of the zero or reference measurement (see 3.1.12 and 3.1.14).

NOTE For examples of parameter changes and their measurement, see Table D.2 and Annex E.

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