



BSI Standards Publication

Geotechnical investigation and testing - Geotechnical monitoring by field instrumentation

Part 3: Measurement of displacements across a line: Inclinoimeters

National foreword

This British Standard is the UK implementation of EN ISO 18674-3:2017+A1:2020. It is identical to ISO 18674-3:2017, incorporating amendment 1:2020. It supersedes BS EN ISO 18674-3:2017, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee B/526/3, Site investigation and ground testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 04566 6

ICS 13.080.20; 93.020

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2018.

Amendments/corrigenda issued since publication

Date	Text affected
31 May 2020	Implementation of ISO amendment 1:2020 with CEN endorsement A1:2020: Section 5.5.1, Table 2 row 4 amended

English Version

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

Reconnaissance et essais géotechniques - Surveillance
géotechnique par instrumentation in situ - Partie 3:
Mesurages des déplacements perpendiculairement à
une ligne par inclinomètre (ISO 18674-3:2017)

Geotechnische Erkundung und Untersuchung -
Geotechnische Messungen - Teil 3:
Verschiebungsmessungen senkrecht zu einer Linie mit
Inklinometern (ISO 18674-3:2017)

This European Standard was approved by CEN on 3 September 2017.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN ISO 18674-3:2017) has been prepared by Technical Committee ISO/TC 182 "Geotechnics" in collaboration with Technical Committee CEN/TC 341 "Geotechnical Investigation and Testing" the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2018, and conflicting national standards shall be withdrawn at the latest by June 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 18674-3:2017 has been approved by CEN as EN ISO 18674-3:2017 without any modification.

Foreword to amendment A1

This document (EN ISO 18674-3:2017/A1:2020) has been prepared by Technical Committee ISO/TC 182 "Geotechnics" in collaboration with Technical Committee CEN/TC 341 "Geotechnical Investigation and Testing" the secretariat of which is held by BSI.

This Amendment to the European Standard EN ISO 18674-3:2017 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2020, and conflicting national standards shall be withdrawn at the latest by September 2020.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 18674-3:2017/Amd 1:2020 has been approved by CEN as EN ISO 18674-3:2017/A1:2020 without any modification.

Contents

Page

Foreword	iv
Introduction to Amendment A1	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Symbols	3
5 Instruments	4
5.1 General	4
5.2 Probe inclinometers	5
5.3 In-place inclinometers	6
5.4 Inclinometer casing	8
5.5 Measuring range, accuracy and repeatability	9
6 Installation and measuring procedure	9
6.1 General	9
6.2 Installation of guide tubes at accessible surfaces and in concrete	9
6.3 Installation of guide tubes in boreholes	10
6.3.1 Drilling of boreholes	10
6.3.2 Installation of guide tubes	10
6.3.3 Securing borehole measuring locations	12
6.4 Installation of in-place inclinometers	12
6.5 Carrying out the measurement	13
6.5.1 Instrumentation check and calibration	13
6.5.2 Measurement	13
7 Data processing and evaluation	14
8 Reporting	15
8.1 Installation report	15
8.2 Monitoring report	15
Annex A (normative) Measuring and evaluation procedure	16
Annex B (normative) Deflectometers	20
Annex C (informative) Backfill materials	24
Annex D (informative) Geo-engineering applications	26
Annex E (informative) Measuring examples	27
Bibliography	38

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 voluntary nature of standards, 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.

This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*.

A list of all parts in the ISO 18674 series can be found on the ISO website.

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 of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

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).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation —

Part 3: Measurement of displacements across a line: Inclinometers

1 Scope

This document specifies the measurement of displacements across a line by means of inclinometers 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 also refers to deflectometers (see [Annex B](#)) to supplement inclinometers for the determination of horizontal displacements across horizontal measuring lines.

NOTE In general, there are two independent displacement components acting across measuring lines. Inclinometers allow the determination of the two components for vertical measuring lines. For horizontal lines, inclinometers are limited to the determination of the vertical component only.

If applied in conjunction with ISO 18674-2, this document allows the determination of displacements acting in any direction.

This document is applicable to:

- checking geotechnical designs in connection with the Observational Design procedure;
- monitoring of geotechnical structures prior to, during and after construction (e.g. natural slopes, slope cuts, embankments, excavation walls, foundations, dams, refuse dumps, tunnels);
- deriving geotechnical key parameters (e.g. from results of pile load tests or trial tunnelling);
- identification and monitoring of active shear planes in the ground.

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 inclinometers as part of the geotechnical investigation and testing in accordance with 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.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18674-1 and ISO 18674-2 and the following apply.

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

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

3.1 inclinometer

system for monitoring displacements across a measuring line by means of inclination measurements in the field

Note 1 to entry: The system essentially consists of an instrument with one or more *tilt sensors* (3.2), a guide tube, a means to measure the position of the instrument in the guide tube and a read-out device.

Note 2 to entry: Data from inclinometers require evaluation, which can be done using proprietary software or spreadsheets.

3.2 tilt sensor

gravity-activated electric sensor for inclination measurements

3.3 probe inclinometer

system comprising a probe with one or more built-in *tilt sensors* (3.2) for step-by-step measurements of the inclination on a measuring line

Note 1 to entry: Also known as a traversing inclinometer.

Note 2 to entry: Vertical probe inclinometers measure displacements in horizontal directions.

Note 3 to entry: Horizontal probe inclinometers measure displacements in vertical directions (settlements or heave).

Note 4 to entry: An alternative to horizontal probe inclinometers is a hydrostatic probe system.

Note 5 to entry: See also Reference [3].

3.4 in-place inclinometer IPI

inclinometer system comprising a single element, or a series of elements, with one or more built-in *tilt sensors* (3.2) in each element, for measurement of the inclination at specific locations on a measuring line without removing the instrument

Note 1 to entry: In-place inclinometers exist which can measure at all inclinations, but when in near-horizontal position, deflections from the azimuth cannot be measured.

3.5 uniaxial inclinometer

system for inclination measurements in a single plane

Note 1 to entry: Common for horizontal measuring lines.

3.6 biaxial inclinometer

system for inclination measurements in two planes 90° to each other

Note 1 to entry: Common for vertical measuring lines.

3.7**inclinometer casing**

guide tube appropriate to the inclinometer system being used

Note 1 to entry: Commonly, the inner side of inclinometer casings have four longitudinal keyways. Commercially available casings differ with regard to material, dimension, type of coupling, number of keyways etc. (see 5.4).

Note 2 to entry: The corners of casings with square section can be considered as keyways.

3.8**gauge length**

L

distance between adjacent contact points of the instrument

Note 1 to entry: For *probe inclinometers* (3.3), L is commonly 0,5 m or 1,0 m.

3.9**base length**

distance between adjacent measuring points used in the evaluation procedure

Note 1 to entry: For *probe inclinometers* (3.3), the base length is equal to the *gauge length* (3.8).

4 Symbols

Symbol	Name	Unit
A	measuring plane of the probe which coincides with the plane of the guide wheels	—
a	lateral displacement component in Plane A	m
B	measuring plane of the inclinometer probe normal to Plane A	—
b	lateral displacement component in Plane B	m
d	depth, distance	m
F	subscript for follow-up measurement	—
h	height with respect to sea level	m
i	number of a measuring point	—
L	gauge length of an inclinometer or deflectometer probe	m
l	distance between measuring points	m
n	total number of measuring points along a measuring line	—
R	subscript for reference measurement	—
t	elapsed time	s
t_F	date and time of a follow-up measurement	—
t_R	date and time of a reference measurement	—
u, v, w	displacement component in x-, y- and z-direction, respectively	m
x, y, z	local coordinates of a guiding tube or borehole	m
α	tilt angle of the probe axis in Plane A	° (degree)
β	tilt angle of the probe axis in Plane B	° (degree)
ψ	angle between guide tube coordinate x and plane A of the inclinometer	° (degree)
θ, ρ	auxiliary quantities	° (degree)

5 Instruments

5.1 General

5.1.1 Probe and in-place inclinometers should be distinguished from each other (see [Table 1](#) and [Figures 1, 2](#) and [A.1](#)).

Table 1 — Inclinometer types

No.	Type	Sub-type	Principal measuring procedure	Automatic data acquisition
1	Probe (see 5.2)	Inclinometer — Vertical inclinometer — Horizontal inclinometer	Probe moved inside a guide tube from one measuring point to the next (see Figures 1 and A.1). Repeated measurements within the measuring period.	Not common
2	In-place (see 5.3)	In-place inclinometer (IPI) — Vertical inclinometer — Horizontal inclinometer — Combined	Instrument inserted into a guide tube and held in measuring position throughout the measuring period	Common

NOTE A combined IPI is a series of elements in which some elements act as vertical and some act as horizontal inclinometers.

5.1.2 Changes of tilt shall be measured by comparison of the measured values with those of the reference measurement. Displacements of the measuring points across the measuring line shall be deduced in accordance with [Annex A](#).

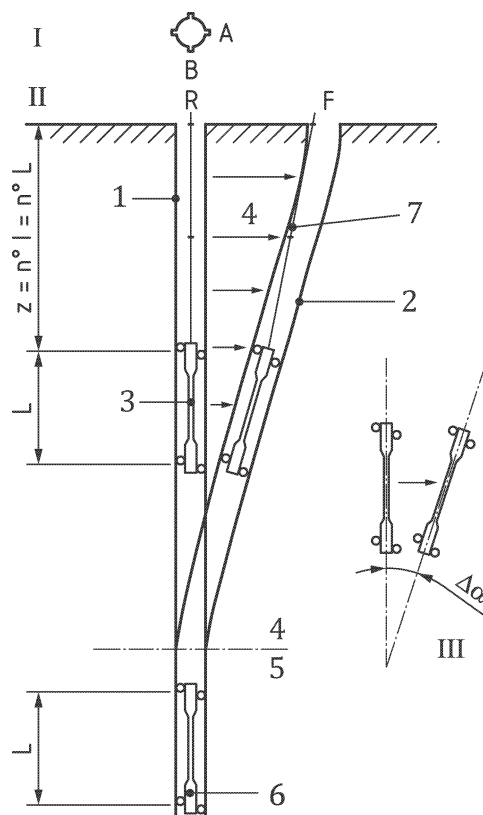
5.1.3 The point to which the measurements are related shall be denoted the “reference point”.

5.1.4 For absolute displacement measurements, the coordinates of the reference point shall be independently determined or assumed as fixed and verified.

NOTE If the reference point is assumed to be at the deepest measuring point, surveying of the inclinometer head can serve as a check.

5.1.5 The sensing element shall consist of a housing with either one (uniaxial configuration) or two (biaxial configuration) built-in tilt sensors. In the case of a biaxial configuration, the tilt sensors shall be installed with axes perpendicular (90°) to each other.

5.1.6 The installation planes of the tilt sensors shall be denoted as the instrument Planes A and B, whereby Plane A shall coincide with the plane of the guide wheel assemblies (see 5.2.5). The planes shall be durably marked onto the inclinometer housing, e.g. by the mark “A+” showing the positive A direction.



Key

1	undeformed inclinometer casing	I	top view of inclinometer casing
2	deformed inclinometer casing	II	side view
3	inclination measuring element	III	detail of inclinometer element in R- and F- positions
4	area of the ground subject to displacements	A	A+ direction
5	undeformed deeper ground for base fixity	B	B+ direction
6	reference point (here, the axis of the bottom wheel is set at the lowest measuring position)	L	gauge length
7	depth measuring device	R	initial position of inclinometer casing at the reference measurement
Δα	change of inclination	F	position of inclinometer casing at a value change measurement

Figure 1 — Measuring concept for inclinometers (schematic)

5.2 Probe inclinometers

5.2.1 Inclinometer probes shall be moved incrementally along the measuring line, whereby each increment shall not exceed the gauge length L of the probe.

5.2.2 The depth measuring device shall have permanent and wear-resistant depth measuring marks. The spacing of the marks should be equal to the gauge length L of the probe.

5.2.3 The length of the depth measuring device and the spacing between the marks shall be checked throughout the measuring project. Changes shall be recorded.

NOTE 1 Monitoring displacements by probe inclinometers requires good repeatability of the probe's positioning at the respective measuring points (see [6.5.2.3](#) and [7.4](#)).

NOTE 2 The use of a cable gate or a suspension pulley can help to ensure good positioning.

5.2.4 Inclinometer casing shall be used as guide tubes (see [5.4](#)).

5.2.5 The inclinometer probe shall be equipped with two spring-loaded guide wheel assemblies. The width of the guide wheels shall fit the keyways of the inclinometer casings. The force of the springs should ensure a central positioning of the probe in the casing, even for extended monitoring periods with repeated measuring runs.

5.3 In-place inclinometers

5.3.1 The principal setup of in-place inclinometers should be as in [Figure 2](#).

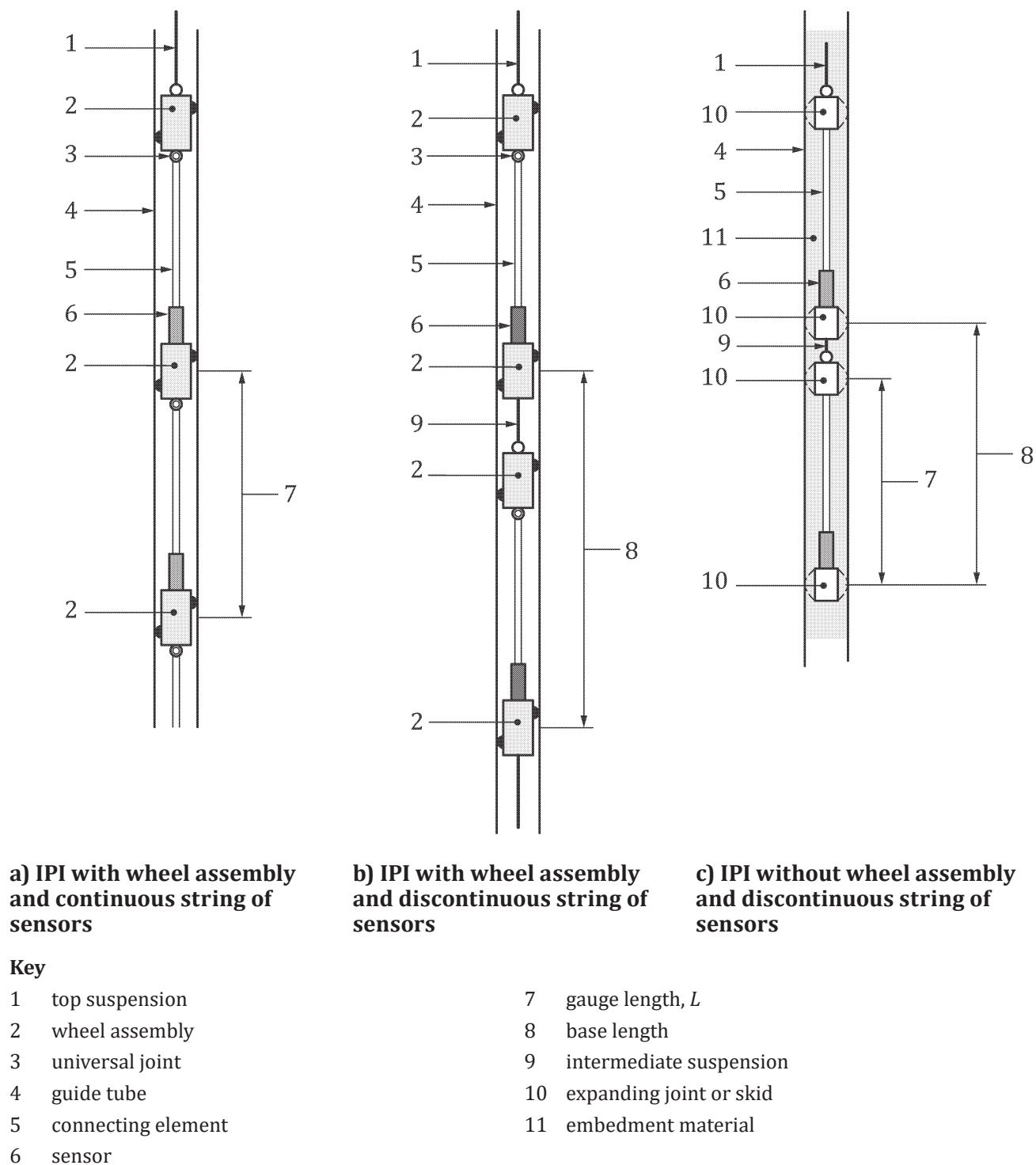


Figure 2 — Principal setup and components of in-place inclinometers (IPIs)

5.3.2 It shall be ensured that the lengths of the connecting elements remain constant throughout the measuring project (no elongation, no shrinkage).

5.3.3 For a continuous string of measuring elements [see [Figure 2 a\)](#)], the flexibility of the measuring elements shall be negligible.

NOTE This requirement applies in particular to horizontal strings (see Reference [\[4\]](#)).