Development of international standards for geotechnical instrumentation under ISO

Josep Raventós[1]

[1]SOCOTEC Spain, I&M and Geotechnical Survey Director- Barcelona- Spain
josep.raventos@socotec.com

ABSTRACT

International standards for monitoring under ISO have been under development since 2010 and the intentions were presented during the 8th International Symposium on Field Monitoring in Geomechanics (FMGM 2011) in Berlin. Progress on this project was reported at FMGM 2015 in Sydney and ISFMG 2022 in London. The base standard on general rules was published in 2015, part 2, the standard on extensometers, in 2016 and in 2017 the third part on inclinometers. Part 4 on piezometers was published in 2020, Part 5 on pressure cells in 2019 and Part 8 on load cells in 2023. These standards have been published as ISO Standards in English and French worldwide. In Europe the standards have been published under EN ISO 18674 member countries of CEN have to publish these standards in their country. The standards on settlement measurements by hydraulic systems (part 6), geodetic measurements (part 9) and strain measurement (part 7) are under development and will be submitted to enquiry in the next few months.

Keywords: geotechnical instrumentation; standards; ISO.

1. Introduction

1.1. Review of development of geotechnical international standards

The development of international standards for monitoring started in 2000 under CEN TC-341 Geotechnical measurements in particular as a task group of working group CEN TC-341/WG1. The development of these standards was always in parallel, under the Vienna agreement, between ISO and CEN, however due to the voting process under ISO, where a majority for work under CEN was not achieved by the ISO members voting outside CEN. Therefore the development had to be transferred under the auspices of ISO TC-182. The working group ISO TC182/WG2 Geotechnical monitoring has been formed in 2015. Essentially all the persons working under CEN have now been working under ISO. The active members of the working group are listed as co-authors of this paper. The development of international standards for monitoring has been reported during previous meetings of FMGM initially in Berlin (Bock, 2011) and then in Sydney (Steiner et al., 2015). Several standards have been published and the present state of publication and development will be reported herein.

1.2. Development of standards under ISO directives

The development of standards under ISO is regulated by ISO Directives and foresees the development of standards under strict rules and enquiry of the standard drafts during development and vote.

Working drafts are developed by the working group and then submitted to the main committee, here ISO TC-182, which decides if the draft shall be submitted to enquiry as Committee draft (CD) or as enquiry draft (ISO/DIS). The committee draft is then circulated to the member bodies for normally8 weeks. The enquiry draft is circulated by 12 weeks. The comments are then sent to the working group for consideration. A final draft is then prepared with deadlines fixed. The final draft is circulated for 8 weeks until it is voted. A two-thirds majority of the voting P- members is required for accepting a final draft and not more than a quarter of the votes are negative.

The formal and structured procedure of development allows that the developed standards become highly accepted in the profession. The developed standards form a reliable basis for geotechnical monitoring as a worldwide consensus has been reached.

2. State of standards

2.1. Published standards

Until 2023 six standars on Geotechnical Monitoring have been published, namely:

Part 1: ISO 18674-1 “General rules”, 31 p.; 2015
Part 2: ISO 18674-2 “Measurement of displacements along a line: Extensometers”, 45 p., 2016
Part 3: ISO 18674-3 “Measurement of displacements across a line: Inclinometers”, 38 p. 2017

Part 4: ISO 18674-4 “Measurement of power water pressure: Piezometers”, 56p p. 2020

Part 5: ISO 18674-5 “Stress change measurements by total load cells” 35p, p 2019

Part 6: ISO 18674-8 “Measurement of loads: load cells”, 30p, p.2023

The table of content of these standards and the main issues treated will be presented in following sections.

2.2. Standard under preparation

Part 7 on strain measurement, Part 6 on Measurement of settlements by means of hydraulic systems and part 9 on displacement measurement by means of geodetic instruments are work in progress status.

3. Contents of published standards.

3.1. General Rules: ISO 18674/1

EN ISO 18674-1 contains 31 pages. Its structure is reflected in the table of contents as shown in Table 2. The contents are essentially self-explanatory as a standard is a condensed set of rules. A detailed discussion would lead to a repetition of the standard. Important points are that geotechnical monitoring is part of geotechnical design. Each monitoring project has to be designed. Terms and definitions have been established. Some key issues will be discussed that are considered important for a monitoring project.

3.1.1. Some basic definitions of a monitoring system

In the standard geotechnical monitoring is linked to geotechnical design. In particular geotechnical monitoring shall be linked to at least one specific question that is to be answered; naturally there may be several questions to be answered. The key issue is that questions are formulated at the initiation of a project and actualized during the project. It is important to identify geotechnical key parameters that shall be measured. The changes of these key parameters from the zero or reference measurements are made. In this context very important definitions are the different measurements that have to be taken during a geotechnical monitoring project from installation to construction period, the following measurements have been defined (Figure 2): Initial measurement (1) Zero measurement (2) Reference measurement (3) The time periods between these key time points are: before the initial measurement is the period of installation of the measuring system, this is followed by the stabilization period before the zero measurements. Then the period of baseline measurements follows until the reference measurement is taken.

3.1.2. Requirements of a monitoring project

The requirements of a geotechnical monitoring project are prescribed. During the different design phases from:

- Initiation phase
- preliminary design phase
- conceptual design phase
- specification design phase (of the monitoring system)
- Installation
- Data collection phase
- Data processing, evaluation and reporting phase

Different aspect in the design of the monitoring project shall be addressed. Geotechnical measurements shall be supplemented by geodetic measurements, if applicable, to support and verify them. A geotechnical monitoring system has to fulfill several severe requirements, as there are complex interactions between the ground and the monitoring system. The system is vulnerable as the communication lines are often located in construction zones. The components of the monitoring system have to be robust in order to function under the mostly severe environmental and construction conditions. The geotechnical measurements are influenced by direct and indirect factors. Direct factors are related to the construction or the object. Indirect factors are temperature and atmospheric pressures, but also high voltage lines, electro-magnetic fields and ground vibrations. A monitoring system should include redundancy, such that with the failure of one component not the entire system fails.

3.1.3. Particular requirements

In Annex A the "Minimum requirements on content of instrument data sheets" are prescribed. It is important that for an instrument or sensor a certain number of data are furnished by the supplier. In order to facilitate communication a definition of the general and local coordinate system (in boreholes) is provided normative in Annex B. A right-hand rectangular coordinate system is defined with the origin of the coordinate system in the collar of the borehole and the zcoordinate follows the axis of the borehole. The use of field measurements in connection with design and constructions of geotechnical structures and the relation to geodetic measurements (Table 3) is given in Annex C. Table 1. Geotechnical and geodetic measurements In Annex D "Measurement and monitoring of geotechnical key parameters" the link between key parameters and different measurement methods is presented. In Annex E types of instruments and monitoring methods are presented with a concise description and sketches.

3.2. Piezometers: ISO 18674/4- Measurement of pore water pressure

The development of the standard on pore pressure measurements with piezometers proves to be particularly challenging. There is a large variety of measuring methods, which is a consequence of different geologic and subsoil conditions and different geotechnical requirements. In a first step one has to distinguish between open and closed systems. For these systems many subtypes exist.

For open systems:

- Standpipe piezometer installed in boreholes
- Small diameter pipe systems with Quartz filter, often called Casagrande piezometers.
- Larger diameter Monitoring wells with seals that might also be used for a pumping test
- Driven piezometers
- Pushed-in piezometers

For closed systems:

- Closed systems with a diaphragm but different transducers and transmission of the signal:
- Pneumatic piezometers
- Hydraulic twin-tube piezometers
- Closed push-in systems

The installation procedures will also be treated and discussed. The nearly most important issue in piezometer installation is the placement of piezometer in boreholes either traditionally with filter packs and sealing with grout or bentonite pellets or the fully grouted method that has advantages but the limits of the method are not yet well known.

3.3. Total Pressure Cells: ISO 18674/5- Measurement of stress change

Total pressure measurements are very challenging because the introduction of the instrument may change the stress distribution within the studied media. The standard provides issues and facts to be considered when designing the measurement system and analysing the obtained measurements.

Two general measurement methods are used according to the physical principal of the applied instrument. These are:

i) Deformation: the deformation of the diaphragm of the cell is used to compute the pressure on the liquid in the intervening cavities. This type of cells tends to be soft.

ii) Compensation: the distance between the platens is measured by means of an externally applied pressure compensation. These types of cells tend to be stiff.

As previously mentioned, the measurement of contact stresses is prone to error, as the presence of an instrument within a medium creates a significant change in the stress distribution within this medium. Therefore, instrument selection and installation are critical as this is the most appropriate way to deal with the inherent error.

Even considering the difficulties of a precise measurement of the absolute value of the stress, total pressure cells are the appropriate instrument to support decision making based on stress changes, as the evolution of the pressure change is a useful information that should be considered in most of the standard geotechnical projects.

According to the installation method, cells can be divided as follows:

i) Embedded, where the instrument is fully embedded in the ground,

ii) Contact, where the instrument is in contact with the structure,

iii) Push-in, where the cell is pushed into the ground; and

iv) Borehole, where the cell is installed in a borehole in the ground.

Annex B of the document provides an overview of cell types and geo-engineering context to help make a decision on the cell type, dimension and installation procedure in order to minimise the error.

Table 1. Content of Annex B of ISO 18674-5.

Applic ation	Suitability – Cell type			
	Embed ment	Con tact	Pu sh-in	Bore hole
Earth dams and embankme nts	+	-	+/-	-
Shallow foundation s on soil or fill	-	+	-	-
Cast-in-place pile foundation	+/-	-	-	-
Soft soil	-	-	+	-
Stiff soil- hard rock	-	-	-	+
Hard rock	-	-	-	+/-
Radial stress in tunnel lining	-	+	-	-

Tangential stress in tunnel lining	+/-	-	-	-
Underground repositories	+	-	-	+/-
Swelling		+		+/-

3.4. Load Cells: ISO 18674/8- Measurement of loads

This standard focuses on the measurement of forces acting in geotechnical structures, such as anchors, struts and tie-backs by means of load cells.

Load cells are instruments that measure forces acting on geo-structural elements, typically placed at the end of the structural element, where forces are transmitted from one element to another.

These instruments can have different measurement principles, for example mechanical or photo-elastic. Most of them are hydraulic or electric, therefore the standard only considers these two last measurement principles.

Hydraulic load cells measure forces by measuring the pressure on a liquid, filling an empty cavity inside the cell that is oriented normal to the acting force. Electric load cells, conversely measure the force by the deformation of an elastic-behaving element which deforms under the applied force.

The load transfer from the structural member to the instrument should be ensured by means of distribution plates and a load bearing element. The material of the load bearing element has to be mechanically stable.

An important consideration to be made when evaluating data is the influence of temperature because temperature influences both the instrument and the structural element in which the measurement is made. To deal with that, the document recommends

i) The use of temperature-compensated instruments, and
ii) Independent temperature measurements in the vicinity of the load cells.

The installation of the instrument is crucial, as usual, to ensure compliance and maximise accuracy of the measuring system. According to the element in which the force measurement is required, several considerations should be made. For example, when measuring forces in struts, the load cell should be placed at one end of the strut and concurrently to ensure structural connections and load transfer.

Annex A of the document provides a suitability analysis of the different load cell types regarding the application, as shown in table 2.

Table 1. Suitability analysis according to annex A of ISO 18674-8.

Application	Load Cell type	
	Electric	Hydraulic
Anchor and tie-back	+	+
Struts in braced excavation	+/-	+/-
Cast-in-place pile	-	+
Steel arch support and props	+	+

4. Conclusions

International Standards have been and are developed under ISO TC-182 Geotechnical Engineering, the International Standard Organization, that provide a frame-work and rules for planning, installing and operating monitoring systems in geotechnical and civil engineering practice. These new standards support engineering design and engineering judgment.

Acknowledgements

We wish to thank for the support from the national standard organization, professional organization and individuals that support the development of these standards.

References

Bock, H. (2011) ‘Geotechnical monitoring standards in Germany: DIN 4107, Parts 1 to 4’, in J Gattermann (ed), Proceedings 8th International Symposium on Field Measurements in Geomechanics (FMGM), Berlin 12 – 16 Sept. 2011, Workshop 3: Standardisation and Product Data Sheets, pp. 45-58.

Bock, H &Thaher, M 2007, ‘Towards European Standards in Performance Monitoring of Geotechnical Structures’, in J DiMaggio & P Osborn (eds), Proceedings 7th International Symposium on Field Measurements in Geomechanics (FMGM), Boston 24 – 27 Sept. 2007, 12 pp., Geo-Institute, ASCE

Dunnicliff J (1997) ‘No more judgment in geotechnical engineering: The professional legacy of ASTM?’,Geotech. News, vol. 15, no. 4, pp. 31-46.

Eurocode 7, Geotechnical design- Brussels (CEN)

ISO/IEC (2017) Directives Part 1, Consolidated ISO Supplement – Procedures specific to ISO, Eighth edition.

Peck R B. (1969) ‘Advantages and limitations of the Observational Method in applied soil mechanics’, Géotechnique, vol. 19, pp. 171-187.

Steiner W.(2011), ‘Geotechnical monitoring standards in Switzerland: SN 670305 - The European Task Group No. 2 of CEN TC 341/WG1 on geotechnical monitoring by field instrumentation’,in J Gattermann (ed), Proceedings 8th International Symposium on Field Measurements in Geomechanics (FMGM), Berlin 12 – 16 Sept. 2011, Workshop 3: Standardisation and Product Data Sheets, pp. 59-65.

Steiner, W., Beth, M., Bock, H., Clegg, M., Golser, J., Möller, B., Pezzetti G., Ridley, A., van der Salm, R., Spalton, Ch., de Vos, L., Welter, Ph., Wörsching, H. (2015) Update on European (EN) and International (ISO) geotechnical monitoring standards; Proceedings FMGM 2015, Sydney, Australia, Australian Centre for Geomechanics, Perth.