Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3

doi: 10.32075/17ECSMGE-2019-0944

XVII European Conference
ECSMGE 2019
Reykjavik
on Soil Mechanics
and Geotechnical Engineering

Tomorrow’s geotechnical toolbox: EN 1997-1:202x General rules

La boîte à outils géotechniques de demain: EN 1997-1: 202x Règles générales

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ABSTRACT: This paper describes the development of the final Project Team (PT) draft of the next generation of Eurocode 7 Part 1 (EN 1997-1:202x). The use of Nationally Determined Parameters and the drive for ease-of-use is highlighted. Key changes from the previous version of EN 1997-1 are explained, including the introduction of the Geotechnical Design Model; revision of the Geotechnical Categories and their application; the implementation of Consequence Classes and Geotechnical Complexity Classes in achieving the reliability required by the Eurocodes; elaboration on the use of numerical methods within Eurocode 7; the treatment of rock on an equal basis with soil; and greater emphasis on the Observational Method.

RÉSUMÉ: Ce document décrit l’élaboration par la PT2 de la version finale de la prochaine génération de l’Eurocode 7 Partie 1 (EN 1997-1: 202x). L’utilisation de paramètres déterminés au niveau national et la recherche de la facilité d’utilisation sont mises en évidence. Les principaux changements par rapport à la version précédente de l’EN 1997-1 sont expliqués, notamment l’introduction du modèle de conception géotechnique; la révision des catégories géotechniques et leur application; la mise en œuvre des classes de conséquences et des classes de complexité géotechnique pour atteindre le niveau de fiabilité requis par l’Eurocode; le développement de l’utilisation de méthodes numériques à l’intrérieur de l’Eurocode 7; le traitement de la roche sur un pied d’égalité avec le sol; et une plus grande importance accordée à la méthode observationelle.

Keywords: Eurocodes, Geotechnical Design Model; Geotechnical Category; finite element method; Observational Method

1 INTRODUCTION

One of the largest ongoing cooperation projects at the European level is developing tomorrow's engineering toolbox, the Eurocodes. Many hundreds of engineers throughout Europe are contributing to the work which aims to develop more harmonised and user-friendly Eurocodes, including Eurocode 7 for geotechnical design.

For geotechnical engineering, the work is coordinated by CEN/TC250/SC7. For EN 1997 Part 1 – *General rules*, a Project Team (PT) was selected with the task of writing and synchronizing different opinions. The work of Project Team 2 (PT2) resulted in a draft of EN 1997 Part 1 – General Rules in April 2018. This paper is prepared by PT2 and highlights some of the key changes from the previous version of EN 1997-1. The following topics are discussed: Geotechnical Categories, Geotechnical Design Model, groundwater, numerical methods, rock engineering, the Observational Method, execution, and documentation.

2 HANDLING INPUT DATA

One of the most critical tasks in geotechnical design is to establish an appropriate description of each design situation, including ground conditions, with sufficient quality and extent of information for the specific geotechnical structure. A relevant Ground Model and Geotechnical Design Model are crucial to ensure a safe, durable and economical design.

2.1 Ground Model

The Ground Model is defined as a model of the ground based on results from ground investigations and other available data.

The Ground Model is based on the factual report of ground properties compiled in the Ground Investigation Report (GIR). Hence, it includes output from desk studies, field reconnaissance of the site and its surroundings, geological studies, field investigation, laboratory testing, and groundwater investigation.

The model includes, for example, derived values of ground properties and groundwater conditions for each identified unit in the ground profile. The assessment of derived values of ground properties, including the applicability and limitation of different test methods, are covered in EN 1997 Part 2.

2.2 Geotechnical Design Model

The Geotechnical Design Model (GDM) is defined as ground information for engineering design purposes, developed for a particular design situation and limit state.

More simply, the GDM is the compilation of all the data needed to design a geotechnical structure in a given design situation. It may be presented as a simple sketch on paper or as a more advanced 2D or 3D model.

The GDM is the output of a review of the available information in the GIR including desk studies, field reconnaissance of the site and its surroundings, geological studies, field investigation, laboratory testing, and groundwater investigation. The GDM includes, for example, selected ground properties of the geotechnical units, geometric details, and groundwater conditions.

The characteristic values included in the GDM are evaluated according to EN 1997 Part 1, with consideration of the accuaracy achieved in the ground investigation, extent of ground investigation, relevance of the ground investigation for the specific geotechnical structure, and natural variation of the ground property. An effort has been made to develop practical rules that will reduce subjectivity in the selection of characteristic values. A scheme that transparently communicates and handles uncertainty in parameter evaluation is proposed, introducing the concept of a "characteristic value assesment procedure". An Informative Annex illustrates the idea and proposes three such procedures in which pre-existing and site-specific information are weighted.

In addition to the characteristic value, EN 1997 Part 1 also defines the "best estimate" value. The best estimate value may be used to predict expected behaviour, whereas the characteristic value is used for verification of limit states.

3 GEOTECHNICAL CATEGORIES AND THEIR DESIGN ASPECTS

3.1 Geotechnical Categories

In EN 1997-1:2004, Geotechnical Categories (GCs) combine the complexity of design (e.g. "difficult ground or loading conditions") with safety aspects (e.g. "exceptional risk"). In the second generation of Eurocode 7, the definition of the Geotechnical Categories is now based explicitly (see Table 1) on the:

- Consequence Class (CC) from EN 1990
- Geotechnical Complexity Class (GCC) defined in EN 1997-1

The assignment of a geotechnical structure into one of the three Geotechnical Categories places certain requirements on the design:

- Minimum amount of ground investigation
- Minimum verification of ground, fill and groundwater conditions
- Minimum validation of calculation models
- Required design checking (and design qualification) level
- Required inspection level
- Minimum amount of monitoring

In addition, modifiers for partial factors may depend on the GC, if specified by a National Standard Body (NSB).

Table 1 Table 4.3 from prEN 1997-1:2018

Consequence Class (CC)	**Geotechnical Complexity Class (GCC)**		
	Lower (GCC1)	**Normal (GCC2)**	**Higher (GCC3)**
Higher (CC3)	GC2	GC3	GC3
Normal (CC2)	GC2	GC2	GC3
Lower (CC1)	GC1	GC2	GC2

3.2 Consequence Classes

The new EN 1990 now includes five Consequence Classes (CC0 to CC4). Structures in CC0 may be designed with alternative rules to those given in the Eurocodes; whereas structures in CC4 can require additional rules.

Table 2 shows the definition of these classes according to the April 2018 draft of EN 1990. Examples of geotechnical structures in these CCs may be given as National Determined Parameters (NDPs) in the new EN 1997-1.

3.3 Geotechnical Complexity Classes

Ground that supports a geotechnical structure shall be classified into one of three Geotechnical Complexity Classes (GCCs), selected according to Table 4.1 (NDP) in the new EN 1997-1. More details may be given in the National Annex.

Geotechnical Complexity Classes deal with the difficulty of the ground conditions (in relation to local experience), the difficulty of obtaining sufficiently accurate ground parameters, the complexity of ground-structure interaction, and the difficulty of groundwater conditions, etc.

As already mentioned, the Geotechnical Categories determine the minimum amount and quality of ground investigation. This appears as a circular loop because we need ground investigation in order to determine the appropriate GCC and, consequently, GC. In practice the loop is broken by considering several design stages of each project, noting that GCs may be changed during project development as more information becomes available. Different geotechnical construction tasks can belong to different GCCs or CCs and therefore are classified in different GCs.

Table 2 Table 4.1 (NDP) of prEN 1990:2018

Consequences class	**Indicative qualification of consequences**	
	Loss of human life or personal injury[a]	**Economic, social or environmental consequences**[a]
CC4 – Highest	Extreme	Huge
CC3 – Higher	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Lower	Low	Small
CC0 – Lowest	Very low	Insignificant
[a]The Consequence Class is chosen based on the more severe of these two columns		

4 NUMERICAL METHODS

Due to the complexity of numerical methods and their rapid and ongoing scientific development, it was not possible to provide a comprehensive set of rules for their use in geotechnical design. Instead, the importance of user competency and validation of outputs is emphasised. The code emphasizes that the application of partial factors to actions, material parameters, and resistances alone does not necessarily ensure a sufficiently reliable verification of a limit state. Verification using numerical methods is also influenced by discretisation of geometry, initial stress states, construction stages, boundary conditions, drainage conditions, constitutive behaviour, and the properties of and interfaces with structural elements.

A set of rules has been drafted on the verification of limit states using numerical methods. SLS verification with displacement-based analysis methods is relatively straightforward. Clauses were added only to highlight the improved predictions that can be obtained with advanced constitutive models and to distinguish between best-estimate predictions of deformation and SLS verification. (The latter tends to involve more cautious values of ground and structure parameters, geometry, sequencing, loading, etc. than best-estimates of actual values.)

ULS verification has always been more contentious and different approaches to applying partial factors have been long debated. Readers are referred to Lees (2013, 2017) for a discussion of the pros and cons of each approach. In simple terms, the Material Factor Approach (MFA) is suited to verifying ULSs involving ground failure and the Effects Factor Approach (EFA) to the verification of structural ULS. Consequently, a dual factoring approach to the determination of design values of structural forces is recommended to allow for cases where MFA provides more onerous values, while ground failure is verified by MFA. Design values of axial force in piles, soil nails, ground anchors and rock bolts would also be determined by the dual factoring approach and the most onerous value compared with design values of axial resistance for these structures.

A significant disadvantage of MFA is that the adoption of design values as input to an analysis might result in different degrees of conservatism depending on the problem type and the nonlinearities involved. Such effects might be amplified in subsequent construction stages. To help overcome this, the code recommends adopting characteristic values throughout a construction sequence and to reduce ground strength in separate adjunct stages at critical phases in the construction sequence.

5 GROUND WATER

As groundwater is very important in all geotechnical design, a full clause is dedicated to characterising its properties and pressures.

Groundwater actions and groundwater pressures are derived from standing (i.e. free) water, groundwater and piezometric levels, which must be established for each design situation. The piezometric level is the level to which water would rise in a standpipe.

Generally, the groundwater levels fluctuate in time and it is a difficult task to choose the appropriate groundwater level for the relevant design situation. Therefore, representative values of piezometric levels are defined, corresponding to an annual probability of exceedance. Based on these piezometric levels, representative values of groundwater pressures can be selected as either:

a) a single permanent value, equal to the characteristic upper or lower value of the groundwater pressure; or
b) a combination of a permanent mean value of the groundwater pressure and a representative variable groundwater pressure, being the amplitude of the groundwater pressure series in time.

The characteristic upper and lower groundwater pressures in case a) are based on a return period of 50 years (this time period is a Nationally Determined Parameter). According to EN 1990, for the representative value of the groundwater pressure amplitude (case b), a distinction is made between (see Figure 1):

- characteristic values, when groundwater pressure is the leading action
- combination values, when groundwater is the accompanying action
- frequent values, to be used in accidental loading
- quasi-permanent values, to be used e.g. for long-term settlement analyses

From the representative groundwater pressure values, design values can be derived by:

- direct assessment, e.g. a maximum groundwater level that cannot be exceeded
- application of a deviation to the representative piezometric level or groundwater pressure, e.g. in case of overall stability or retaining wall design
- applying a partial factor to the representative groundwater pressure or its action effects, e.g. in case of calculating bending moments in rigid structural elements.

Ultimate limit states for uplift and hydraulic heave are also described in the new Eurocode, using a new formulation from that of the previous code.

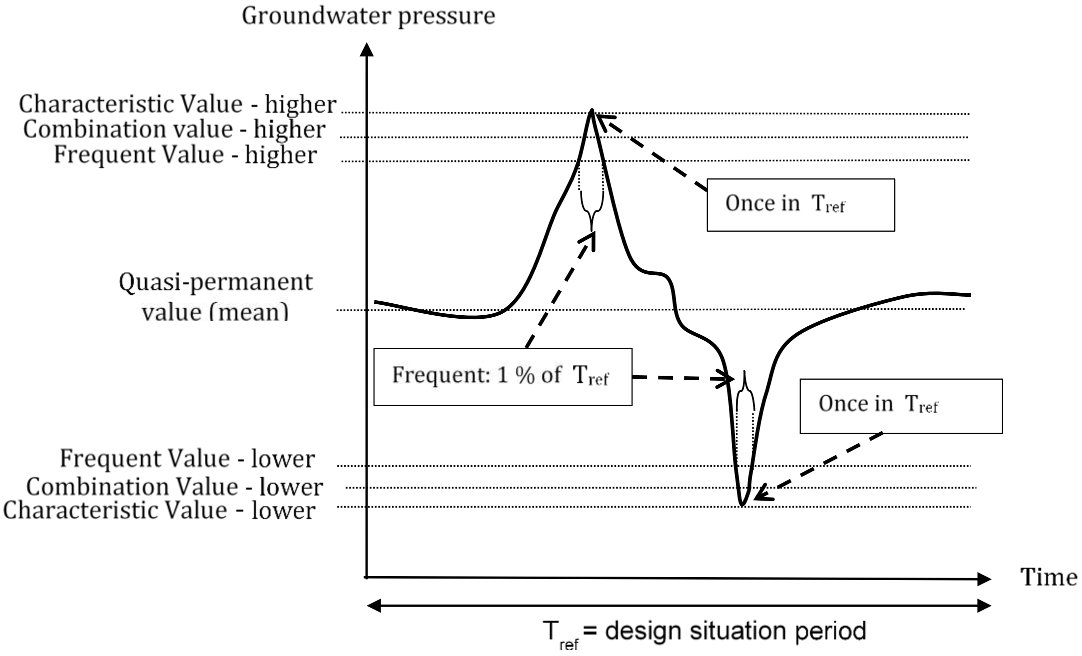

Figure 1 Figure 6.1 of prEN 1997-1. Representative values of groundwater pressures – illustration of characteristic, combination, frequent, and quasi-permanent values

6 EXECUTION AND CONTROL

Clause 10 of EN 1997-1 deals with issues related to the implementation of the design during execution of the works, by supervision, inspection, performance monitoring and maintenance. It specifies that planning for the above will be documented in the design in suitable plans. It is also specified that the objectives, type, extent, and level of these plans shall comply with the specific requirements of EN 1997-3 and relevant execution standards.

The Supervision Plan specifies acceptance criteria for any visual or other observation and/or measurement taken during supervision with the aim of verifying design assumptions and indicating what course of action is required if the acceptance criteria are not met. Suggestions are given for the contents of the Supervision Plan for geotechnical structures in different Geotechnical Categories.

The Inspection Plan specifies the objectives, type, methods, quality, and frequency of inspection of the works with the aim of checking that execution is carried out according to the design and that all design revisions are adopted. Three inspection levels are suggested, one for each Geotechnical Category.

The Monitoring Plan specifies the types, locations, frequency, and acceptance criteria of the required monitoring. Suggestions are given for the contents of the Monitoring Plan in each Geotechnical Category.

The Maintenance Plan describes any maintenance that is required to ensure the safety and serviceability of the structure after construction.

7 ROCK

The original version of EN 1997 was developed largely based on classical soil mechanics. However, according to the mandate for PT2, the revised version of the code should treat soil and rock on an equal basis.

The draft version has therefore used the word 'ground' in all clauses that apply to both soil and rock. If the words 'soil' or 'rock' are used, it indicates that the text is only applicable for the specified ground type. Careful wording has been necessary to ensure that the general rules in EN 1997-1 are equally relevant for rock and soil. Further development and alterations will be needed to ensure that the most common rock applications can be verified using EN 1997.

8 OBSERVATIONAL METHOD

Clause 4.8 of EN 1997-1:202x deals with the Observational Method, one of the permitted alternative methods for verifying limit states of geotechnical structures.

When using the Observational Method, different sets of assumed behaviour of the geotechnical structure should be established, covering all foreseeable geotechnical parameters, ground responses, and ground-structure interactions. For each set of behaviours, a design variant shall be established and verified together with a set of relevant alarm values. Suitable monitoring, observation, and testing plans shall be specified so that the assumptions for each design variant can be verified or rejected based on the alarm values. The results of monitoring, observation and testing shall be assessed at regular intervals and the design variant matching the actual geotechnical behaviour shall be put into operation immediately, if the alarm values for the current design variant are exceeded.

9 REPORTING

All recommendations and requirements on reporting that were previously spread across different clauses, have been collected in a single clause. EN 1997-1:202x sets out requirements for what shall be reported, but not the format. For simplicity, information that should be reported during the design and building phase is split between four different reports. However, the division is optional and it is possible (nationally) to choose another division of the reports.

The amount of reporting and level of detail is linked to the Geotechnical Category (with less required for GC1). The four reports are:

- Ground Investigation Report (GIR)
- Geotechnical Design Report (GDR)
- Geotechnical Construction Record (GCR)
- Geotechnical test reports

Annex E gives an overview of the expected contents of each report type.

10 CONCLUSIONS

The aim of the original version of Eurocode 7 to create a common toolbox for geotechnical design across all of Europe was an ambitious one (to say the least). Not only were the design of different geotechnical structures brought under one code, but so too were the design practices of all the participating countries. Although complete harmonisation of design was not possible, EN 1997-1:2004 provided a common framework for geotechnical engineers to practise, discuss, and learn geotechnical design more easily. That was a highly significant achievement of the first draft of Eurocode 7.

Now, in response to feedback from the European geotechnical engineering community, an improved version of Part 1 has been drafted (as summarised in this paper). We hope this paper will foster further discussion on geotechnical design practice across Europe at this conference.

11 ACKNOWLEDGEMENTS

Comments received from members of the National Standards Bodies, from SC7's Task Groups, and from other members of the European geotechnical engineering community on the October 2017 draft of prEN 1997-1 are gratefully acknowledged.

The authors would also like to thank their collegauree on SC7 for many hours of fruitful discussion on the subject of geotechnical design.

12 REFERENCES

Lees, A. (2013) Using numerical analysis with geotechnical design codes, in Modern Geotechnical Design Codes of Practice (eds. Arnold, Fenton, Hicks, Schweckendiek and Simpson). IOS Press, Amsterdam.

Lees, A. (2017). The use of geotechnical numerical methods with Eurocode 7, Proceedings of the ICE Engineering Analysis and Computational Mechanics.