Proceedings of the 21st ICSMGE, Vienna, Austria, 14 – 19 June 2026. Pistrol, Adam & Schweiger (eds.)
Published by: ÖGG, Austrian Society for Geomechanics, Salzburg, Austria, ISBN 978-3-9503898-4-5
https://doi.org/10.53243/ICSMGE2026-775

2nd Generation of Eurocode 7 – Geotechnical Reliability and Representative value

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ABSTRACT: In the 2nd Generation of Eurocode, the verification and design of a geotechnical structure shall achieve an appropriate reliability level, according to EN 1990. The input parameters, calculation model, design process and execution shall have an appropriate quality and precision. In EN 1990, the amount and type of measures to be taken are linked to the consequence class; however, for a geotechnical structure, the ground complexity and the interaction between the ground and the structure need to be considered to select appropriate measures. Hence, the 2nd Generation of Eurocode 7 introduced the Geotechnical Complexity Class, which, in combination with the consequence class, gives the Geotechnical Category, a tool to identify the relevant measures needed to achieve appropriate reliability. This paper introduces Geotechnical Reliability, including the different measures proposed by Eurocode 7. In addition, the paper elaborates on the possibilities for each country to adjust and complement the system to align with its national regulations and practices. The 2nd Generation of Eurocode 7 emphasises the importance of selecting representative values of ground properties, considering the uncertainty in the information available from the Ground investigation. This paper briefly mentions the different sources of information and describes how uncertainty is considered in determining the representative value, using both nominal and characteristic values.

KEYWORDS: 2nd Generation of Eurocode, Geotechnical Category, Geotechnical Reliability, Representative value

1 INTRODUCTION

The 2nd Generation of Eurocode provides the engineer with the necessary tools to ensure that any structure verified, designed, and executed according to Eurocodes, with an appropriate level of reliability, and hence appropriate probability of failure, fulfils the fundamental requirements of safety, serviceability, durability, robustness, and sustainability. The proper levels of reliability are set as a national standard, based primarily on the potential consequences and causes of failure, as well as the cost of mitigation and public aversion to failure.

Geotechnical reliability was introduced in EN 1997-1:2024 as a general tool to provide verification, design, and execution that is accurate and precise, sufficient for the consequences of failure, while also considering the ground's complexity and interaction with the geotechnical structure. The measures provided are linked to four areas: uncertainty of the ground, models and design, implementation of the design, and error prevention. The measures provided in the 2nd generation of Eurocodes may be adjusted at the national level to better align with national legislation and practice.

2 GEOTECHNICAL RELIABILITY

2.1 *Geotechnical reliability vs Structural reliability*

The basis of design in the 2nd generation of Eurocodes is formulated in EN 1990:2023 for all structures, regardless of whether they are multi-storey apartment buildings, bridges, or geotechnical structures. Compared to the 1st generation rules previously found in Eurocode 7 related specifically to geotechnical engineering, have been reformulated into general concepts and transferred to EN 1990:2023.

The structural reliability, consequence classes and the appropriate level of reliability are now found in EN 1990:2023 now include reference to the complexity of the ground for geotechnical structures. However, there are differences in the work approach between structural and geotechnical engineers, as shown in Figure 1. The structural engineer may primarily rely on facts, then select, calculate, and build. In contrast, the geotechnical engineer needs to anticipate, minimise uncertainty, use engineering judgment, and adapt the structure to the site's ground conditions. To account for these differences, there is a need to further develop structural reliability into a flexible tool that also accounts for the ground complexity and interaction with the structure. In the 2nd generation of Eurocode 7, geotechnical reliability is introduced using an enhanced version of the geotechnical category as the tool for categorization.

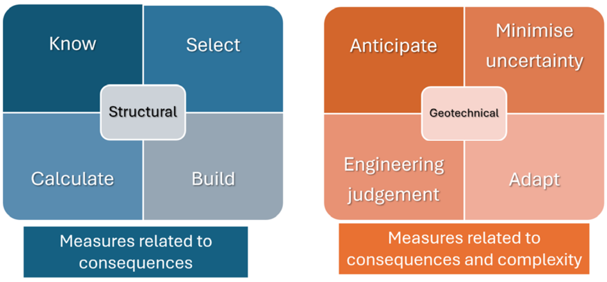


Figure 1. Contrast in work approach between a structural and a geotechnical engineer. Illustration of contrasts (source: Van Seters and Franzén, 2021).

Reliability and specifically geotechnical reliability, including the possibility to use reliability-based verification of limit state, is further elaborated in a report prepared by CEN TC250/SC7/TGC3 (EC JRC, 2024b).

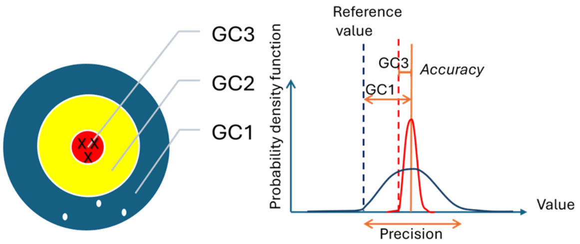
2.2 *Geotechnical Complexity Class, GCC*

The ground conditions at the site will vary, and, depending on the interaction with the geotechnical structure, the need for measures to ensure accuracy and precision in the design may differ. For sites with high variability or uncertainty in ground conditions, the extent and type of measures differ compared to a site with homogeneous ground conditions and low uncertainty. The need for measures is also influenced by the sensitivity to water and the complexity of the ground-structure interaction.

The 2nd generation of Eurocode 7, therefore, introduces the Geotechnical Complexity Class, GCC, as a tool for categorisation of the site. The GCC is selected using engineering judgment, utilising the results of the Ground investigation compiled in the Ground Model (GM). The selection of GCC may vary throughout the site and be altered as the work progresses with design and construction phases, as the knowledge of the site increases.

2.3 *Geotechnical Category*

The Geotechnical Category in the 1st generation of Eurocodes was a classification tool that accounted for both the ground complexity and the failure consequences. The 2nd generation of Eurocodes has a more systematic approach to categorisation, judging consequences and geotechnical complexity independently, before combining them into a single Geotechnical Category. Figure 2 illustrates how the Geotechnical Category is the outcome of combining the Geotechnical Complexity Class with the Consequence Class. For the geotechnical category 3, GC3, it is necessary to implement measures to ensure that the design and execution are accurate and precise, as errors will have severe consequences. For the geotechnical category 1, GC1, it may be acceptable to tolerate less accuracy and precision, as the consequences are minor, and hence fewer measures are required.



	GCC1	GCC2	GCC3
CC3	GC2	GC3	GC3
CC2	GC2	GC2	GC3
CC1	GC1	GC2	GC2

Figure 2. Illustration of combining consequences and geotechnical complexity into a Geotechnical Category.

3 MEASURES TO ACHIEVE RELIABILITY

3.1 *Main causes of failure and improper function*

Uncertainty in ground conditions, limitations of the calculation models, and human factors are often cited as the primary causes of failure or improper functioning of geotechnical structures. Human factors include both errors in both design and execution, poor communication and organisational issues with a lack of clear division of responsibilities. To limit the risk of failure and improper functioning, mitigation measures must be activated, which are proportionate to the consequences and complexity.

The measures that Eurocode 7 recommends, based on Geotechnical Category, are risk mitigation measures that ensure that the verification, design and execution have the appropriate reliability. The Eurocode 7 recommended measures, as summarised in Figure 3, are divided into four areas: uncertain ground conditions, design models, design implementation and error prevention.

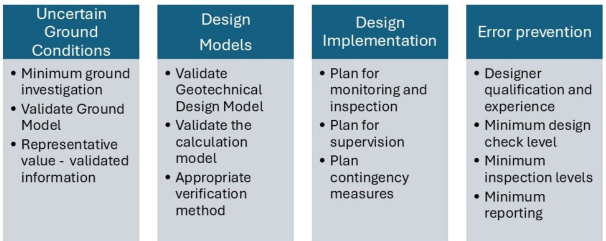


Figure 3. EN 1997 recommended measures to ensure appropriate reliability.

3.2 *Description of the ground*

The building material for geotechnical engineers is the ground. The Ground Model (GM) and the ground properties are anticipated based on the ground investigation. To ensure that the Ground Model and properties are sufficiently accurate and precise, Eurocode 7 recommends the following measures:

- There is a minimum of ground investigation that needs to be undertaken to ensure a necessary base for description of the ground. The extent, type and depth depend on the type of ground and geotechnical structure.
- The Ground Model should be validated, using available information and comparable experience.
- The compiled information in the Ground Investigation Report should be validated. Derived values should be thoroughly documented, including their known limitations and associated uncertainties.

Eurocode 7 provides tables that give guidance on the extent of the measures depending on the Geotechnical Category. These tables may be adjusted at the national level.

3.3 *Models and design*

Geotechnical engineers use multiple types of models in the verification and design of the geotechnical structures. It is crucial that all models are sufficiently accurate and precise for their intended use. Eurocode 7 recommends the following measures:

- Validate the Geotechnical Design Model GDM), which contains all necessary information for the considered design situation, geotechnical structure and associated limit state.
- Validate that the calculation model used is applicable for the considered design situation. This applies to analytical, empirical and numerical models.
- Select an appropriate verification method for the design (calculation, testing, prescriptive rules or the Observational Method).

Eurocode 7 provides recommendations on the measures that may be adjusted at the national level.

3.4 *Implementation of design in execution*

The design prepared by the geotechnical engineer will need to be adjusted based on the findings at the site during execution. Hence, it is essential to identify critical aspects to verify during execution indicating whether the design base (GM, GDM) is valid or if contingency measures need to be implemented.

Eurocode 7 recommends that the following plans are prepared and used in the execution:

- Inspection plan: Validation of the ground conditions, but also structural members of the geotechnical structure.
- Monitoring plan: Validate the ground and system behaviour.
- Supervision plan: Check that the work is performed according to the execution specifications.
- Maintenance plan: with the necessary measures that will be needed during the design service life of the structure.

In addition, Eurocode 7 recommends that a plan for contingency measures to be prepared.

3.5 *Prevent errors*

Human errors, including a lack of effective communication, are critical to be avoided to ensure the success of a design and its execution. Within the framework of quality management, Eurocode identifies the need for the designer's qualification and experience, as well as the necessity of design checks and site inspections. Eurocode 7 links these requirements to the geotechnical category, and EN 1990:2023 provides further recommendations.

Eurocode relies on the assumption that the user is a competent engineer, and adequate communication exists between the individuals involved in data collection, design, verification and execution. The measures recommended by Eurocode 7 serve to demonstrate the compliance with these assumptions and, at the same time, to limit the probability of errors.

4 REPRESENTATIVE VALUE

4.1 *Two approaches to obtain a representative value*

For geotechnical engineers, the available data to determine the representative value of the ground properties is often limited. The available information needs to be complemented with comparable experience, engineering judgement and available information from the desk study. Hence, the strict formulation of the characteristic value as a statistically determined value, requiring an extensive amount of data, is often not feasible.

To increase the applicability for geotechnical engineers, Eurocode 7 introduces a nominal value as an accepted alternative to determine the representative value. Figure 4 illustrates the differences between the 1st and 2nd generations of Eurocode 7.

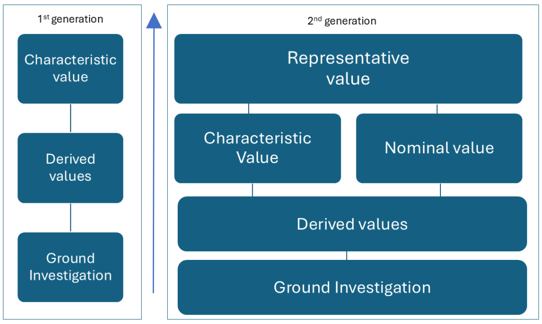


Figure 4. Determination of ground properties in the 1st and 2nd generation of Eurocode 7.

The 2nd generation of Eurocode 7 allows two different approaches to determine the representative value. However, the same uncertainties should be considered, and in theory, the selected value should be the same. The only difference is whether the value is determined by statistical analyses or engineering judgment. If the two values determined are not the same, they should be re-assessed to identify why, and hence to select the appropriate representative value.

4.2 *Sources of information*

Ground investigations are the primary source of information for determining the representative value of geotechnical parameters. For the 2nd generation of the Eurocodes, EN 1997-2:2024 has been reorganised to further support the geotechnical engineer in selecting the appropriate ground investigations to determine the required ground properties.

Ground investigations include:

- Desk study with factual information on the site history, geology, details of any previous ground investigations report in the vicinity of the site and experience related to the site.
- Site inspection within the zone of influence of the geotechnical structure, with inspection and geotechnical mapping of the visible ground surface.
- Preliminary and design investigation, with relevant field and laboratory investigations.
- Monitoring results from the site that give additional information about the ground behaviour.

In the 2nd generation, information on relevant ground investigation method standards and their applicability has been updated and organised into different clauses in EN 1997-2:20024, based on the primary ground properties to be determined. This gives the geotechnical engineer the possibility to select the appropriate ground investigation techniques, being aware of the methods' limitations and applicability to the specific design situation.

The information from the ground investigation is compiled in a Ground Investigation Report (GIR) and forms the basis for assessing and further developing the Ground Model for the site.

4.3 *Selecting the representative value*

In both the 1st and 2nd generations, there is a list of items that should be considered in selecting representative values. There are slight differences in the wording; however, the content is the same and may be summarised as:

- Pre-existing knowledge, including all information available from the desk study and related projects.
- Uncertainty in the quantity and quality of the data.
- Uncertainty due to the spatial variability of the measured property.
- The zone of influence of the structure for the considered limit state, throughout the design service life.

The representative value should be determined for each geotechnical unit in the ground model that has been prepared based on the information compiled in the Ground Investigation Report.

Depending on the failure mode, the representative value should be determined as either the average mean value (Type A) or the high/low value (Type B), as shown in Figure 5. This depends mainly on the ground volume involved in the ultimate state. The determination should consider the natural variation of the ground properties including the spatial variability, the uncertainty and applicability of the used investigation method, the relevance of the transformation model and the amount of information. For the characteristic value, these items are determined as values that will be used in the statistical calculation. For the nominal value, engineering judgement is used to account for the same information and obtain a cautious estimate of the average value or the high/low value.

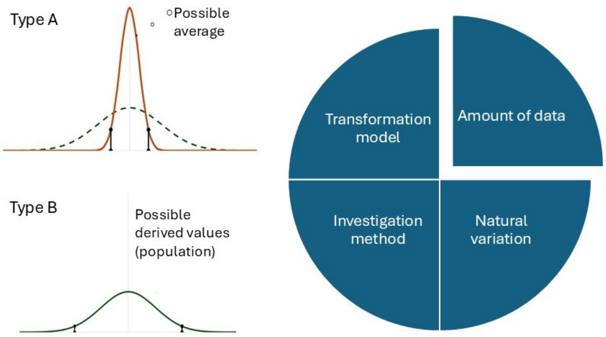


Figure 5. Illustration of the determination of the representative value as an average versus a high or low value with consideration of the related uncertainty.

Regardless of whether the representative value is determined as a characteristic or nominal value, the key is that the geotechnical engineer should be confident that the selected representative value accounts for the uncertainty and, in addition, should be able to estimate the accuracy and precision of the selected representative value.

For the Geotechnical Category 3, it is of utmost importance that the selected representative value has sufficient accuracy and precision. If the available information is insufficient to prove this, additional ground investigation may be necessary.

Further guidance on representative values is given in the JRC report prepared by CEN TC250/SC7/TGC1 (EC JRC, 2025).

5 CONCLUSIONS

Eurocodes provide the framework to demonstrate that the fundamental requirements for safety, serviceability, durability, robustness, and sustainability are fulfilled with an appropriate level of reliability, considering the consequences of failure and inappropriate function of the structure. To account for the differences in work approach between a structural engineer and a geotechnical engineer, Eurocode 7, in its 2nd generation, further developed the concept of structural reliability in EN 1990:2023 to include the complexity of the ground, thereby achieving geotechnical reliability.

The geotechnical reliability, as described in Eurocode 7, provides risk mitigation measures to ensure that an appropriate level of reliability is achieved. The aim is to mitigate the risks associated with ground conditions, models, design, execution, and human factors. Eurocode 7 provides recommendations that may be adjusted at the national level to accommodate national legislation and practices. The importance is to recognise the need to account for the risks in the design process and limit their influence on the design and execution.

One of the primary challenges for a geotechnical engineer is selecting an appropriate representative value of the ground properties. The 2nd generation of Eurocode recognises this challenge by clarifying that two different approaches may be used: the nominal or characteristic value approach. Both approaches account for the same uncertainties but open a clear path for the geotechnical engineer to use either engineering judgement or statistics, or indeed both, to determine the representative value.

The 2nd generation of Eurocode 7 has improved the clarity of the geotechnical design process and added the necessary flexibility for geotechnical engineers, accounting for the differences in work approach between structural engineers and geotechnical engineers. Accordingly, the geotechnical engineer must, to a large extent, anticipate and base the designs on engineering judgement while using appropriate ground investigations, design models, measures for implementation of the design to achieve geotechnical structures with the required reliability. The 2nd generation of Eurocode provides valuable tools for the design of geotechnical structures.

ACKNOWLEDGEMENTS

The authors would like to acknowledge that the evolution of Eurocode 7 from the 1st to the 2nd generation would not have been feasible without the extensive contributions and efforts of our colleagues in TC250/SC7 and the corresponding national mirror groups. The work on Eurocode 7 has resulted in the 2nd generation, which will be a valuable tool for practising Geotechnical Engineers in Europe and also worldwide.

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