Chapter F – Geotechnical calculations

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Introduction

Conventional methods for the design and dimensioning of geotechnical structures mainly aim to analyze the resistance to failure of an isolated structure. These analytical or semi-analytical methods only consider very simple geometries and provide little or no information on the ground deformations surrounding the structures.

The increasingly intensive use of urban spaces and soils, occupied by a variety of structures close to each other, makes it necessary to control the interactions between structures. The designer of a structure must justify that the displacements induced by its construction remain below the threshold set by the client. Traditional methods do not meet this requirement, which explains the increasingly frequent use of numerical modeling and software dedicated to geotechnics that are adapted to design offices. Specifically, digital modeling is used in two different situations:

- during the design phase, to justify the dimensions when traditional methods are difficult or impossible to implement,
- as an expertise tool, to study the behavior of a damaged structure, to identify the phenomena responsible for a specific issue, and to justify the use of a strengthening method.

Depending on the case, models with various levels of complexity can be used, considering the uncertainty of the natural soil's behavior and their spatial variability. Consequently, it becomes difficult to choose a constitutive law and determine its parameters. The user often has to choose between a robust model whose operation is well understood, but which does not account for all the complexity of soil behavior and a model that is potentially more accurate to describe the actual behavior of soils, but which includes many parameters whose roles are sometimes difficult to identify and quantify.

The philosophy behind the design rules promotes the first approach, to use simple and robust models and ensure the safety of the design by inputting appropriate factors and carrying out parametric studies to estimate the sensitivity of the results with respect to the said parameters. However, this approach may lead to an oversimplification of the problem and can lead to overly conservative and unnecessarily costly designs.

The other approach is to use constitutive models that attempt to better represent different aspects of soil behavior. A very large number of models have been proposed, but their practical use remains difficult. Furthermore, the idea of having one "universal" model that describes all phenomena is an illusion and should be abandoned. It is necessary to define the limits of the model chosen: a perfectly plastic elastic model or one considering isotropic strain-hardening, even with a complex load surface and strain-hardening law, cannot predict a progressive accumulation of deformation in a soil mass.

Therefore, the use of finite elements requires the user to have a critical perspective on the soil constitutive model. Though, this is not the only aspect to consider: the result of the calculations can depend essentially on the 3D geometry of the structure and the geometry of the soil layers. It is sometimes (not always) justified to simplify the representation of the soil behavior and to focus on the representation of the construction process. In any case, the results of numerical simulations should be carefully verified.

Finally, it is clear that geotechnical structures are made of soil, in contact with soil, or totally or partially buried; thus, numerical modeling must represent the mechanical interaction between the soil and the structure.

This chapter is organized as follows: it summarizes the main features of numerical calculations in geotechnics before briefly presenting the verification principles adopted in Eurocode 7. Once these elements are presented, recommendations are suggested for good practice using FE calculations in geotechnics. It also deals with the features of dynamic calculations.

F.1 Geometrical aspects

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F.2 Material non-linearities

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F.3 Soil-structure interactions

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F.4 Hydraulic effects

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F.5 Uncertainties and recommendations

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F.6 Normative aspects: Principles of Eurocode 7

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F.7 Dynamic modeling

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F.8 Characteristic scales

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Conclusions and references

This chapter presents an overview of the issues raised specifically by FE calculations in geotechnics, in statics or dynamics. Specific precautions should be taken when performing the calculations concerning the meshing, boundary conditions, phasing, the choice of constitutive models, and the setting of parameters.

With a certain amount of practice and the constant concern to control the obtained results, a wide range of problems and structures can be dealt with. However, there are still situations that are difficult and/or costly to deal with numerically.

Firstly, difficulties may arise due to the ambiguous mathematical structure of the studied problems. In dynamics, choosing a time discretization coherent with all the input data remains difficult. In statics, managing several non-linearities of different natures (unilateral contact, damage) may lead to numerical issues hard to overcome.

One should also remember that the physics of certain phenomena remain poorly understood and described, which is reflected in the numerical analysis. It is the case for various problems such as the initiation and evolution of landslides, implementation conditions of tasks such as the compaction of backfill materials, the initial state of stresses, water content, and other parameters linked to the history of the structural elements, etc.

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