F5. Uncertainties and recommendations

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1. **Uncertainties**

There are many sources of uncertainty in geotechnics. The first is the relative lack of knowledge of the geometry of the soil layers that make up the solid being studied. In addition to the geological knowledge about the area where the structure stands, the main sources of information are the boreholes drilled on the project site. The extrapolation between boreholes, especially if they are far apart and not located at the exact location of the future structure (which may be modified after reconnaissance, for example in the case of tunnels), does not necessarily give an accurate representation of local variations in layer thickness.

In urban areas, the presence of heterogeneities (cellars, wells, foundations of previous structures) is often difficult to detect.

The other source of uncertainty already mentioned concerns the initial state of stresses (and possibly pore pressures) in the soil mass. It can have a major influence on the results of the calculation: this is particularly clear in the case of tunnels, where the loads considered depend on the initial stresses.

Finally, the choice of constitutive models and the determination of the parameters of these models introduce a significant uncertainty on the representativeness of the calculations: if the constitutive model does not capture a phenomenon that controls the behavior of the structure, the result may be qualitatively and quantitatively very far from reality.

2. **Recommendations**

In general, the user must be aware of the objectives of the calculation he is undertaking: the approach is different depending on whether one is trying to justify dimensions or to evaluate the influence of certain constructive provisions (the number and position of the struts, for example).

One must also be aware of the modeling choices on which the calculation is based (even if these choices are sometimes partly imposed by the software). One must be able to identify the phenomena to be taken into account, which leads to the choice of a quasi-static or dynamic analysis, the consideration or not of the hydromechanical coupling, etc.

One must choose between a 2D or 3D calculation. Three-dimensional calculations remain rare for the moment because of the time required to prepare the calculations. However, for some problems, it is clear that two-dimensional calculations can only give a poor indication of the behavior of the studied structure regardless of how long the engineer took in determining the soil parameters. For instance, the study of the stability of the tunnel face cannot be considered outside a three-dimensional context. The same is true for the study of bolt reinforcements of the tunnel face. The development of pre-processors specific to each application should simplify the use of 3D calculations and improve the representativeness of many finite element analyses.

In geotechnics, special focus should be given to the choice of soil parameters: it could be the subject of a whole book. Most advanced constitutive models do not come without a detailed and robust parameter identification procedure, mainly because the model equations cannot be solved even for a simple problem such as triaxial compression. One must therefore calibrate the parameters so that the modeling of triaxial tests, for instance, outputs results in satisfactory agreement with the test results. A trial and error procedure is used, and since the agreement obtained is evaluated subjectively (because we can choose to better reproduce one part or another of the experimental curves), it is not guaranteed that two users will obtain the same parameter values from the same tests. Thus, all constitutive models do not have the same qualities. Some have many parameters, each of which influences a particular aspect of the soil response (but which does not necessarily appear in the available test results). Other models, on the contrary, have a relatively small number of parameters, but each of them can simultaneously modify several aspects of soil deflection. It makes the calibration much more complex.

The last recommendation that must be kept in mind is to check the calculations as much as possible. There are not yet any general tools to measure the quality of a calculation: research work aims to provide error estimators, but their use in geotechnics remains rare. It is therefore necessary to look in-depth at the results: some inconsistencies are sometimes easy to detect. If there are any doubts, it is useful to have the results checked by someone else. In any case, it is highly recommended to carry out parametric studies to get an idea of the influence of certain factors, in particular soil parameters, if it is not certain that their influence on the results is moderate and that their value has been determined with acceptable accuracy.

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