Chapter 5
Limit States for Earth Structures

5.1 Principles of Design Procedure for Earth Structures

The design of earth structures has gone through many changes in time. Roughly until the end of the nineteenth century, the designs that prevailed were based on practical experience gained to-date, i.e. on the experience of our predecessors, who had been building earth structures for centuries, millenniums. Their experience resulted in a set of different rules, recommendations, which gradually even found their way to some technical standards, technical codes. Very briefly said, we should exploit the “know how” of our predecessors.

These are, for example, recommendations concerning the allowable height of the vertical walls of earth excavations that can be built without protective measures, the recommended gradients of upstream and downstream slopes of low earthfill dams (e.g. up to 10 m) built as homogeneous of a certain type of soil, the measures to apply for erosion protection of slope both in embankments and cuts, or what measures to choose with a view to the protection of the earth structure from the negative effects of frost etc. This design procedure using the recommended measures is still respected, mainly in structures with low risks for their environment.

5.1.1 Risk Principle in the Design of Geotechnical Structures – Geotechnical Categories

Today, the basic criterion in the design procedure of earth and generally all geotechnical structures is that of risks. Thus, the risk principle comes to the foreground when considering the design of individual types of earth structures. This principle was applied in some Czech standards as early as 1967 and, in particular, in 1987 – see ČSN 731001 “Foundation soil under shallow foundations” where 3 basic approaches (geotechnical categories) were clearly defined, which combined both simple and complex foundation conditions, or less and more demanding structures. The first geotechnical category was the case of a combination of simple foundation conditions with an undemanding structure, the second geotechnical category referred to a combination of simple foundation conditions and a demanding structure, or
an undemanding structure built in complex foundation conditions. Finally, the third geotechnical category was based on a combination of a demanding structure built in complex foundation conditions. These geotechnical categories were respected in the design principle as well, in the given case the design of spread footing; for 1st geotechnical category it was necessary to ensure that the contact pressure at the underside of footing would not exceed a value shown in a table for the respective soil and foundation depth. Second geotechnical category required verification through calculations of the basic limit states, the limit state of bearing capacity and the limit state of deformation, which, however, was done on the basis of characteristic soil parameters recommended for individual soil types and their consistency characteristics. It was only 3rd geotechnical category that required tests on undisturbed soil samples, and the sets of results then served for defining characteristic parameters of soil properties (mainly with a view to shear strength and deformation characteristics). These characteristic values were reduced using partial safety factors thus providing calculation values of soil properties to be used for the calculation of individual limit states.

Today, this principle is included even in Eurocode 7 Geotechnical Design – Part 1: General Rules of 2004. EC 7 e.g. states that: In order to establish minimum requirements for the extent and content of geotechnical investigation, calculations and construction control checks, the complexity of each geotechnical design shall be identified together with the associated risks. In particular, a distinction shall be made between:

- Light and simple structures for which it is possible to ensure that the minimum requirements will be satisfied by experience and qualitative geotechnical investigation, with negligible risk,
- Other geotechnical structures.

EC 7 does not specify individual geotechnical categories as explicitly as ČSN 731001, being based on a more general quantification. Geotechnical Category 1 should only include small and relatively simple structures, where there is negligible risk in terms of overall stability or ground movements and in ground conditions, which are known from comparable local experience to be sufficiently straightforward. In these cases the procedures may consist of routine methods for foundations design and construction. Geotechnical Category 2 should include conventional types of structures and foundations with no exceptional risk or difficult soil or loading conditions. It should also normally include quantitative geotechnical data and analysis to ensure that the fundamental requirements are satisfied. Therefore routine procedures for field and laboratory testing and for design and execution may be used. Further on, it gives examples of structures or their parts, including earth embankments. Also, it more closely specifies embankments for transport infrastructure and for small dams. Geotechnical category 3 then covers all other structures, which do not fall into Geotechnical category 1 and 2, these, in general, being “large or unusual structures, structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions, structures in highly seismic areas or structures in areas