Chapter 7
Earth Structures in Water Engineering

Earth structures in water engineering are one of the oldest constructions, certainly of these, which are now called civil engineering. Some of them are very old, about 5 000–5 500 years, as for example the small dam Mokhrablur in Armenia (close to the town Kasak), or Jawa in Jordan (close to the town Mafrag). Their earliest role in providing storage for irrigation water formed a major contribution to the development of our civilization. The height of such dams steadily increased but still was only around 20 m in 1800. It is worth mentioning the dam Horná Hodruša in Slovakia with a height of 21.4 m from 1614 or the system of small (fish pond) dams in South Bohemia close to the town Třeboň from the end of the sixteenth century.

The height of embankment dams is of considerable geotechnical interest in consideration to the stresses and water pressures created. The world’s highest embankment dams exceeded 100 m in 1926, 200 m in 1968 and 300 m in 1980 (Nurek, Rogunski) – e.g. Penman (1986), Lukáč and Bednárová (2001), Votruba et al. (1978).

The main reason for dam construction was water storage when there was a surplus and its utilization when there was limitation for both for irrigation and drinking water. Then also, water retention during extreme surplus – during floods – to limit the negative impact of floods on property below the dam profile. Last but not least, this aim is connected with the utilization of water energy, firstly for powering different machinery, and today mostly for electric energy production.

During the interaction of an earth structure with retained water our attention is devoted to the observation of seepage of water through the soil. In Section 5.3.1.3 resp. 5.3.2.3 the attention was devoted to steady flow, when the outflow from the soil element is equal to the inflow for the unit of time. The best way to demonstrate steady flow is a flow net, where a set of flow lines represent lines along which water is passing and a set of equipotentials are lines connecting places with the same water pressure, e.g. Fig. 5.53. With the help of a flow net we can determine the:

- Amount of water seeping through the soil body (e.g. sealing layer),
- Magnitude of pore water pressure in individual points of earth structure,
- Magnitude of hydraulic gradient for the individual element in the earth structure,
- Magnitude of seepage pressure applied on this individual element.
With the help of this information, the safe design of an embankment dam can be made reflecting all relevant limit states of this earth structure as limit states of type GEO, HYD and UPL. With a change of water level in a water reservoir the character of seepage changes from steady flow to unsteady flow. It is necessary to control the limit states also for the unsteady flow, and the problem is more difficult. Therefore the finite element method can be used, e.g. Kazda (1990).

Individual group of problems are connected with the influence of embankment dams on the environment. Already a great impact is connected with dam construction. Water reservoirs flood previous existing areas of fauna and flora (and very often with historical buildings), punctuate sediment transport, transport aquatic animals, mainly fish, significantly change underground water seepage in the immediate environment and can lead to waterside erosion. We can even speak about the aesthetics of dam construction, about their integration into the surrounding environment.

Last but not least, we have to speak about risk assessment, about the risk of the failure of the dam on the area below the dam profile, e.g. Stewart (2000). The design, construction and monitoring of the dam have to take this risk into account, e.g. De Mello (1977).

It is not the aim of this chapter to specify the details of all the problems associated with all types of earth structures in water engineering, but to focus only on some specific examples, which can be decisive for the safe design and maintenance of these earth structures. Specific attention will be devoted to the potential risk of crack creation in the core of earth and rock-fill dams, Vaníček (1988). The solution of this problem bears many new opinions on the construction of earth and rock-fill dams as from a theoretical view (tensile strength of soils, inter-particle forces) to a practical view on how to adjust the design of new fill dams to these new findings. At the end of the chapter some specific problems of small old earth fill dams as well as anti-floods dams will be presented.

### 7.1 Basic Cases of Earth Structures in Water Engineering and Their Features

The range of earth structures used in water engineering is very wide. Instead of classical fill-dams, which were briefly mentioned in the introduction and will be dealt with in more detail later on, we can distinguish between:

- Dams for storing reservoirs of drinking water or water used for different utilization such as for fire-fighting – fluctuation of water level is rather small, in a very limited range.
- Dams for lakes (ponds) – once during a one or two year period the lake is completely drained to harvest all fish bred there.
- Dams for hydroelectric power plant reservoirs (pumping station) – specificity is given by great fluctuation of water level, practically once a day the reservoir is emptied and filled again. The direction of seepage in the earth structures changes all day.