DESIGN OF ROCKFILL PROTECTION LAYERS AS SPILLWAYS ON OVERTOPPABLE EARTHDAMS

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In Germany a big number of new flood retention reservoirs are mapped for the following decade to obtain a sufficient protection against an increasing number of flood events. Due to environmental and landscape architectural reasons state authorities decide more and more to perform several small reservoirs for local flood control instead of a big one. Most of the dams of those reservoirs are not provided with conventional concrete spillways anymore. Instead of that, earthdams can be designed as partly or completely overtoppable for flood relief.

Without a slope protection on the overtopped zone on the downstream face the dam would get eroded immediately in case of overtopping, starting at the toe of the dam. Thus it is absolutely necessary to protect the soil by a protection layer. The protection can be achieved by a layer of rocks placed on a filter layer.

Rockfill spillways on overtoppable earthdams can be designed by placing of regular (cuboidal) resp. irregular shaped stones or by a multi-layer filling of loose stones. The stability of a protection layer with single-layer placed stones is obtained by gravitation forces as well as the grouting forces between the single stones. To increase stability the gaps can be filled with lean concrete. The roughness that can be achieved with the irregular shaped stones is much higher than the one with regular shapes. That results in lower flow velocities, higher flow depths and a lower energy dissipation at the toe of the dam. Compared to the placed stones a multi-layer filling construction type is much easier to carry out. Another advantage is the discharge through the slope protection layer whose magnitude depends on its void fraction. As the roughness of that construction type is quite high, the enery of the overtopping water dissipates mainly on top as well as inside of the slope protection layer. The critical energy dissipation at the toe of the dam can be reduced by such a relatively high roughness. Erosion of the stones of the multi-layer filling can be prevented by enclosing them with an usual geogrid. Those so-called geogrid-mattresses are another favourable alternative for overtoppable earthdams.

The safety of the complete dam structure depends mainly from the safety of the spillway. If the spillway fails, the complete dam will fail as well. Thus it is absolutely necessary to know under which impacts the spillway will collapse.

The hydraulic loads on a rockfill spillway cause reactions of the slope protection layer resp. of their single elements. In the worst case those reactions lead to a failure of the protection layer. Those reactions can occur as sliding of the whole protection layer, erosion of single stones or disruption of the protection layer (fig. 1).

For the multi-layer filling of loose stones large scale experiments for the failure scenarios sliding of the whole protection layer and erosion of the single stones have been accomplished. For the experiments the thickness d_{pl} and the length L of the protection layer was varied as well as the slope angle α and the specific discharge q.

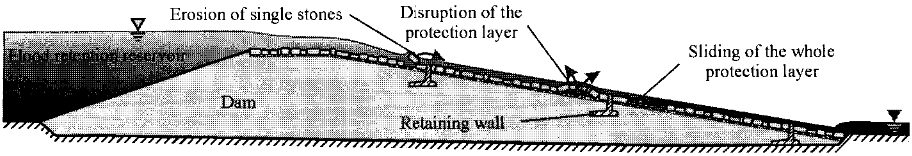

Fig. 1 Failure scenarios of overtoppable earthdams with a rockfill spillway

The measurements on the failure scenario sliding of the whole protection layer have shown that the forces F due to overtopping in case of those rough and porous protection layers do mostly consist of the components parallel to the slope of the gravitation forces of stones and waterbody. Forces caused by the hydrodynamic pressures on the single stones as they occur on single-layer placed stones [Rathgeb (2001)] can be neglected because on the one hand the flow velocities here are a lot smaller due to the high roughness of the protection layer and on the other hand the negative and positive hydrodynamic pressures compensate as a sum of all the stones of the protection layer. By aid of the performed experiments a design proposal could be worked out where the flow depth y is determined which is subject to the specific discharge q, the slope a the thickness of the protection layer d_{pl} and the roughness k. When the flow depth y is known, the sliding safety η_{slide} can be calculated by comparing the friction force F_f (calculated with the friction angle φ) with the gravitation forces parallel to the slope.

For the investigations on erosion, stones with varying sizes were subject to different discharges at different slope angles. After every experiment the eroded stones have been weighed and the diameters have been detected. The experiments have been performed for different time periods. This approach allowed to examine erosion rates as well as sizes of the eroded stones. The experiments have shown that for slopes of 1:15 and 1:10 the maximum possible discharge was not high enough to obtain a significant steady erosion. Only an initial erosion of some stones on top of the protection layer which were situated in an unfavourable position could be observed. At a slope of 1:6 for lower discharges no erosion occured apart from the above mentioned initial erosion, for higher discharges more or less constant erosion rates could be observed after the abating initial erosion. To find out which stone sizes will be eroded at a certain discharge, for the eroded stones stone size distribution curves have been generated. It could be seen, that the steepness of the curves decreases with an increasing specific discharge q_o. That means the fraction of bigger stones increases with the discharge. For a steady proposal for the safety against erosion the number of so far performed experiments is not large enough as the fluctuation of the parameters like stone size and erosion rate is too high. More experiments with slopes of 1:4 and 1:3 will be carried out presently.

The performed experiments are an important component on a way to understand and to design protection layers on overtoppablé earthdams. Ongoing experiments will lead to a large number of information about the behaviour of the stones in case of overtopping.

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