Stepped Spillway Aerator

In hydraulic engineering the energy dissipation capacity of spillways and energy dissipators is a key element to minimize the erosion potential of the flow downstream of a dam and thus to ensure its stability against failure during floods. Stepped spillways allow to continously dissipate a considerable amount of the kinetic energy such that the downstream stilling basin where the residual energy is dissipated by hydraulic jump can be largely reduced in dimension compared to a basin at the toe of a conventional smooth chute. Also, the cavitation risk along the spillway decreases significantly due to smaller flow velocities and the large air entrainment rate. Stepped spillways or cascades are thus a combination of spillway chute and energy dissipator.

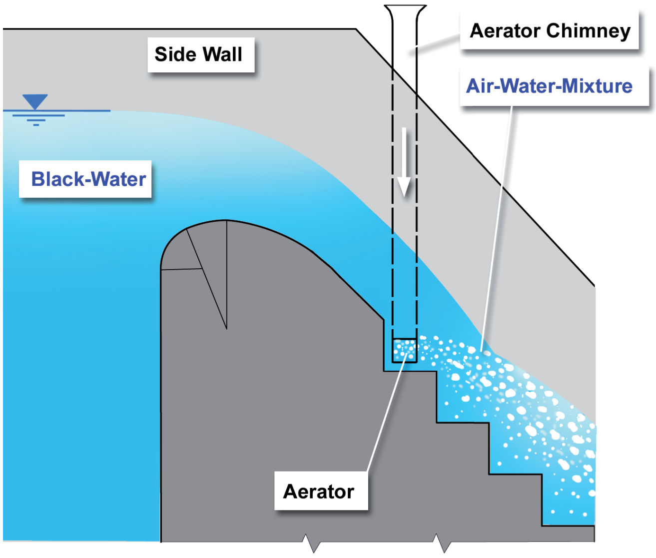

Fig. 1: Scheme of a potential aerator on a stepped cascade.

Stepped spillways have regained popularity over the last two decades thanks to financial benefits resulting mainly from:

- the simple, economic and rapid construction procedure, especially with the roller compacted concrete (RCC) construction method, and
- the aforementioned economic savings with the downstream energy dissipator due to the high amount of energy dissipation along the chute.

The RCC placement in layers enables a simultaneous and thus economic construction of the spillway steps on the downstream dam face. Another common application is the use of stepped overlays on the downstream face of hydraulically unsafe embankment dams as emergency spillways to safely pass a flood such as the PMF over the crest of the dam.

The macro-roughness of the steps significantly reduces flow velocities and leads to flow aeration along the spillway. In contrast to conventional smooth spillways the cavitation risk is therefore markedly reduced.

Nowadays stepped spillways tend to be designed for increasing dam heights and design discharges due to the good experience gained with the RCC construction method. This raises the question on the application limits of stepped cascades. Up to date unit discharges do not exceed q = 25 to 30 $m^3/s/m$ (Minor 2000), which is far below the maximum discharges of q = 200 to 280 $m^3/s/m$ (Volkart1984) for smooth chutes. This limitation comes from the fact that the inception point of air entrainment moves downstream with increasing unit discharge, leaving a longer spillway stretch Li without air bubbles counter-acting cavitation damage at the concrete surface. For a typical gravity dam stepped spillway with a dam height of Hdam = 60 m and a unit design (Index d) discharge of qd = 40 $m^3/s/m$, e.g, only about one third of the total chute length becomes aerated at the downstream end. According to Mateos Iguácel & Elviro Garcia (1992) the critical flow velocity on stepped spillways with respect to cavitation inception is about ucrit = 13 to 15 m/s. These values are below the critical velocities for conventional spillways due to the exposed macro-roughness of the steps in the flow, leading to a higher cavitation potential. For the design example mentioned, the velocity at the inception point amounts to u ~ 26 m/s, so that the risk of cavitation damage, which according to Volkart (1984) increases with u6, cannot be neglected.

As a result of the short comings mentioned above, a systematic study on spillway aeration on stepped spillways as a measure against the inception of cavitation erosion for high unit discharges is undertaken at VAW. For conventional spillways, where the air entrainment takes place significantly further downstream compared to stepped chutes, the placement of aerators to artificially aerate the spillway invert locally has proved to be an effective measure against cavitation damage. The application of this principle to stepped spillways (Fig. 1) is therefore a research topic of great interest to dam design engineers.

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Laboratory of Hydraulics, Hydrology and Glaziology
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