Closure to "Air–Water Flows and Head Losses on Stepped Spillways with Inclined Steps"

Yvan Arosquipa-Nina

Research Fellow, School of Civil Engineering, Univ. of Queensland, Brisbane, QLD 4072, Australia.

Rui Shi

Research Fellow, School of Civil Engineering, Univ. of Queensland, Brisbane, QLD 4072, Australia.

Davide Wűthrich

Assistant Professor, Dept. of Hydraulic Engineering, Delft Univ. of Technology, Delft 2628 CN, Netherlands. ORCID: https://orcid.org/0000-0003-1974-3560

Hubert Chanson

Professor in Hydraulic Engineering, School of Civil Engineering, Univ. of Queensland, Brisbane, QLD 4072, Australia (corresponding author). ORCID: https://orcid.org/0000-0002-2016-9650. Email: h.chanson@uq.edu.au

This paper presents a closure to "Air–Water Flows and Head Losses on Stepped Spillways with Inclined Steps" by Yvan Arosquipa Nina, Rui Shi, Davide Wüthrich, and Hubert Chanson. https://doi.org/10.1061/(ASCE)IR.1943-4774.0001701.

The writers thank the discussers for their contribution. Their discussion focused on a comparison between present and previous data in terms of head losses. Herein, the writers would like to point out some seminal differences between the data sets, which should not be ignored in any data comparison, result interpretation, and conclusions.

Readers should be very careful in interpreting the graph and empirical correlations proposed by the discussers because of the key differences between the different data sets. Several studies showed that the rates of energy dissipation are drastically underestimated when the air–water flow properties are not accounted for (Wood 1983, 1985; Wüthrich and Chanson 2014; Zhang and Chanson 2018; Chanson 2022). The data in the original paper were derived from detailed air–water flow measurements, which should be considered as most reliable and accurate. In contrast, the other data (Chinnarasri and Wongwises 2004, 2006; Li and Yang 2020) are clear-water flow data, ignoring the air–water flow properties through the air–water column and intrinsically the effects of free-surface aeration. The size of the experiments was further different. In the absence of detailed air–water properties, the (air–water) flow velocity is underestimated, and the residual energy is grossly underestimated, with adverse impact in terms of stilling basin design.

Past and present works (Zhang and Chanson 2018; the original paper) demonstrated that the rate of energy dissipation in skimming flows on stepped spillway is directly linked to the step cavity shape, cavity recirculation processes, and associated form drag. With inclined upward steps ($\delta < 0$), the step cavities are more compact than the elongated step cavities observed with downward step cavities ($\delta > 0$). Similarly, the cavity shape is more elongated on flat slope stepped chutes. Altogether, the rate of energy dissipation on a stepped chute is a function of the chute slope, cavity shape, flow Reynolds number, rate of self-aeration, and flow regime: that is, nappe flow, transition flow, and skimming flow.

In summary, any future studies of skimming flows should focus on the fundamental air–water flow physics, that is, on the form drag processes and the interactions between step cavity recirculation and main stream, taking into account the air–water flow properties measured in a large-size physical facility under carefully controlled flow conditions.

References

Chanson, H. 2022. "Energy dissipation on stepped spillways and hydraulic challenges—Prototype and laboratory experiences." *J. Hydrodyn.* 34 (1): 52–62. https://doi.org/10.1007/s42241-022-0005-8.

Chinnarasri, C., and S. Wongwises. 2004. "Flow regimes and energy loss on chutes with upward inclined steps." *Can. J. Civ. Eng.* 31 (5): 870–879. https://doi.org/10.1139/l04-052.

Chinnarasri, C., and S. Wongwises. 2006. "Flow patterns and energy dissipation over various stepped chutes." *J. Irrig. Drain. Eng.* 132 (1): 70–76. https://doi.org/10.1061/(ASCE)0733-9437(2006)132:1(70).

Li, S., and J. Yang. 2020. "Effects of inclination angles on stepped chute flows." *Appl. Sci.* 10 (18): 6202. https://doi.org/10.3390/app10186202.

Wood, I. R. 1983. "Uniform region of self-aerated flow." *J. Hydraul. Eng.* 109 (3): 447–461. https://doi.org/10.1061/(ASCE)0733-9429(1983)109:3(447).

Wood, I. R. 1985. "Air water flows." In *Proc., 21st IAHR Congress*, 18–29. Rotterdam, Netherlands: A.A. Balkema.

Wüthrich, D., and H. Chanson. 2014. "Hydraulics, air entrainment, and energy dissipation on gabion stepped weir." *J. Hydraul. Eng.* 140 (9): 04014046. https://doi.org/10.1061/(ASCE)HY.1943-7900.0000919.

Zhang, G., and H. Chanson. 2018. "Effects of step and cavity shapes on aeration and energy dissipation performances of stepped chutes." *J. Hydraul. Eng.* 144 (9): 04018060. https://doi.org/10.1061/(ASCE)HY.1943-7900.0001505.