Discussion of "Cavitation Potential of Flow on Stepped Spillways" by K. Warren Frizell, Floriana M. Renna, and Jorge Matos

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Hubert Chanson[1]

[1]Professor, School of Civil Engineering, Univ. of Queensland, Brisbane, QLD 4072, Australia. E-mail: h.chanson@uq.edu.au

The authors presented a very interesting contribution to the topic of stepped spillway hydrodynamics. Based on a water-tunnel study, they presented some detailed flow features, for example, in terms of the strain rate, which are valuable to designers. The authors stated that "stepped spillways have no documented damage." It is partially correct. Indeed no cavitation damage and sign of cavitation pitting were reported on stepped spillways after more than 3,000 years of operation, but there were documented damages and failures of stepped spillway systems (Marsh 1957; Jansen 1983; Pravdivets 1993; Chanson 1995b, 2000, 2001a). In this discussion, a number of prototype stepped spillway tests are reviewed and the operational experiences are discussed with a focus on the stepped chute performances.

Several prototype stepped spillway tests were conducted in China, Russia, Germany, the United Kingdom, and Africa. Some extensive tests were performed on the Dachaoshan rollercompacted concrete (RCC) Dam spillway in 2002 with discharge per unit width up to 72 m^2/s (Lin and Han 2001; K. Lin, personal communication, 2002, 2012). Detailed inspections after each series of test indicated no damage or any sign of pitting. A series of tests conducted at the Dnieper hydroplant were performed with discharges per unit width up to 59.4 m^2/s, velocities up to 23 m^2/s, a step height of 0.405 m, and water depths between 0.5 and 3 m (Grinchuk et al. 1977). No damage was reported. Full-scale tests were undertaken in the Sorpe Dam spillway in 2002–2003 to investigate some jump-wave instabilities (P. Kamrath, personal communication, 2003). Some field tests were conducted successfully on the Brushes Clough Dam spillway in the United Kingdom up to 1 m^2/s, although for a short duration (Baker 1994). Some inspection of the M'Bali RCC Dam stepped spillway after a wet season operation showed no sign of damage and pitting (Bindo et al. 1993).

Further, a number of prototype overflow events were documented worldwide (Chanson 1995b, 2001b). In China, the

(a)

(b)

Fig. 1. Paradise Dam stepped spillway (Australia) in operation (spillway geometry: $\alpha = 57.4°$, $h = 0.62$ m, RCC structure): (a) $q = 19\ m^2/s$ on December 30, 2010 (shutter speed: 1/8,000 s); (b) $q = 7.4\ m^2/s$ on March 5, 2013 (shutter speed: 1/1,600 s)

Fig. 2. Hinze Dam stepped spillway (Australia) in operation (spillway geometry: $\alpha = 51.3°$, $h = 1.2$ m, rockfill dam wall with conventional concrete spillway): view from downstream for $q = 14\ m^2/s$ on January 29, 2013 (shutter speed: 1/8,000 s)

Shuidong Hydropower Station experienced a peak flow of 90 m^2/s (He and Zeng 1995). The RCC dam spillway was protected by conventional concrete steps ($h = 0.9$ m) with an 8-cm chamfer. A movie documentary showed no abnormal operation and inspections after the flood event indicated no sign of damage. In Queensland (Australia), the operational record of several overflow stepped weirs demonstrated the soundness of the timber crib piled weir design. A structure, Cunningham weir, was overtopped for more than 2 months in 1956, with a maximum discharge per unit width in excess of 60 m^2/s. Only minor damage was experienced and the weir is still operational today. Between 2010 and 2013, several stepped spillways operated during a succession of major flood events. Figs. 1 and 2 illustrate the operation of two structures. No damage to the stepped chutes was reported despite some exceptional flood events lasting for weeks. These examples are only a few and there are ample documentations on stepped spillway operations, including historical records, in Europe, America, Asia, and Australia.

In hydraulic engineering, there is no better proof of design soundness than a successful operational record. This is particularly true with stepped spillway structures, which are in use for more than 3,000 years (Chanson 1995a, 2001a). A number of field tests of stepped spillway structures showed a sound operation of the prototype spillways with discharges per unit width up to 72 m^2/s. These investigations are complemented by a large number of prototype experiences with stepped spillway operation during major to exceptional floods (up to 90 m^2/s). All the observations indicated an absence of cavitation pitting and damage to the steps. The long-lasting successful operation, for more than 3,000 years, highlights the design soundness of stepped spillways, while emphasizing the importance of expert hydraulic engineering during the design stages.

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