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ENHANCED ENERGY DISSIPATION IN STEPPED CHUTES[1]

Discussion by H. CHANSON[2]

The writers (JAMES et al. 2001) must be congratulated for their innovative paper. Their contribution is a timely reminder that most research on stepped chute hydraulics has been narrowly limited to flat identical horizontal steps in straight prismatic rectangular channels (Chanson 2001). For completeness, the discusser wishes to provide relevant information on early stepped spillways and related works. He also adds some pertinent comment.

Enhancement of energy dissipation may be provided by superposition of small and large steps. In Australia, the Malmsbury (1870) and Upper Coliban (1903) stepped spillways were designed with a combination of large drops (h = 2 to 4 m) and stepped chutes (h = 0.305 m) (Fig. 1, Chanson 2001, pages 48 & 73). At design flows, the drops operate with a nappe flow and the chutes in skimming flow regime. Their successful operation for more than a century suggests that the design is sound. On the model of the Kennedy's Vale dam (h/l = 1), Stephenson (1988) superimposed occasional large steps to smaller steps and he observed a 10% increase in energy dissipation for this model.

Two early French stepped spillways were equipped with V-shaped steps. Completed in 1834, the Tillot dam spillway was equipped with two series of small V-shaped steps (oriented forward) (App. I). Note the channel convergence and the absence of downstream stilling basin (Fig. 2). The Pas du Riot dam was completed in 1873 and it is equipped with a masonry stepped chute. The steps are sloped upwards and V-shaped, oriented backwards (Fig. 3). The spillway capacity was increased during the 1990 dam refurbishment, without modification of the original stepped chute. Both stepped spillways are still in use, highlighting the soundness of design.

While the writers showed the effects of step lateral deflections on the rate of energy dissipation, they did not elaborate on three-dimensional flow patterns nor construction practice. Step deflections are expected to induce shock waves and sidewall standing waves that affect the sidewall design and chute operation. Three-dimensional effects will further be amplified in non-straight channels. In a flat stepped chute (h/l = 0.06), Chanson and Toombes (1997) measured sidewall wave heights in excess of the critical depth (see also Toombes 2002). They also observed splashing heights exceeding three to five times the critical depth, and they documented one prototype experience. Practically a lateral deflection of steps lacks geometrical

[1] by James, C.S., Main, A.G., and Moon, J., *Water & Maritime Engineering, Proc. Instn. Civ. Engrs.*, 2001, Vol. 148, No. 4, pp. 277-280.

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simplicity : e.g., it is not suitable for roller compacted concrete construction. Altogether these issues may offset the advantages of the design.

Overall the authors must be congratulated for their innovative results. Their contribution highlight the needs for further comprehensive studies of stepped chute hydraulics with non flat horizontal steps.

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Appendix I - History of the Tillot dam

Built between 1830 and 1834, the Tillot dam was designed for the water supply of the Canal de Bourgogne (France). The structure is a straight rubble masonry gravity dam with 4 downstream buttresses (dam height ~ 9.2 m). In 1838, the dam wall had to be reinforced. The catchment area is 5.5 km^2, the reservoir capacity is 0.52 E+6 m^3 and the annual rainfall is about 850 mm (Orth 1934)

The spillway, located on the right bank, is a rubble masonry construction (Fig. 2). It consists of a long flat crest followed by 2 series of 4 steps (Table I-1). There is no downstream energy dissipator. The design flow rate is 19 m^3/s.

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Table I-1 - Step dimensions of the Tillot dam spillway

Drop No. (1)	W (m) (2)	h (m) (3)	l (m) (4)
1	5.5	0.68	1.18
2	5.2	0.62	1.24
3	4.8	0.41	0.83
4	4.5	1.18	8.6
5	2.35	0.91	1.11
6	2.2	0.56	1.24
7	2.2	0.64	1.44
8	2.3	1.08	N/A

Note : W : channel width.

Fig. 1 - Upper Coliban stepped spillway (1903, Australia) 5 December 1997 (Courtesy of R. Smyth, Coliban Water) - Dam height : 30 m - View from the dam wall - Note the large drop upstream of the bridge and a series of smaller steps downstream

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Fig. 2 - Tillot dam stepped spillway (1834, France) in January 1997 Note the small V-shaped steps (oriented forwards) in the lower series of steps and the surrounding snow

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Fig. 3 - Pas du Riot dam stepped spillway (1873, France) in November 1994 - Dam height : 34.5 m - The spillway intake was enlarged in the 1990s without modification of the stepped chute