Discussion of "Hydraulics of Broad-Crested Weirs with Varying Side Slopes" by J. E. Sargison and A. Percy

January/February 2009, Vol. 135, No. 1, pp. 115–118.
DOI: 10.1061/(ASCE)0733-9437(2009)135:1(115)

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

The authors presented a useful contribution on the hydraulics of broad-crested weirs, showing some influence of the weir inflow design on the bottom pressure distributions and discharge coefficient. It is highlighted herein that the inflow geometry including the rounding of the weir upstream edge has a marked effect on the flow pattern and discharge coefficient.

A broad-crested weir is a flat-crested structure with a crest length large compared to the flow thickness for the streamlines to be parallel to the crest invert and the pressure distribution to be hydrostatic (Henderson 1966; Montes 1998; Chanson 2004) (Fig. 1). For an ideal fluid flow above a rectangular weir, the Bélanger principle yields the relationship between the flow rate Q and upstream head above crest H_1 (Jaeger 1956)

$$\frac{Q}{b} = \sqrt{g\left(\frac{2}{3}H_1\right)^3} \tag{1}$$

where b=channel width; and g=gravity acceleration. Eq. (1) was first proposed by Bélanger (1841). In real fluid overflows, a dimensionless discharge coefficient C_d is commonly introduced

$$C_d = \frac{Q/b}{\sqrt{g\left(\frac{2}{3}H_1\right)^3}} \tag{2}$$

where $C_d=1$ for an ideal broad-crested weir overflow.

Experimental observations and theoretical considerations demonstrated that the weir inflow geometry had a major influence on the flow pattern and discharge coefficient (Bazin 1896; Mos 1972; Isaacs 1981). Fig. 2 illustrates the effect of the relative weir height P/H_1 and of the upstream corner rounding on the streamline pattern for a rectangular broad-crested weir with vertical upstream wall. All the sketches are drawn for the same upstream

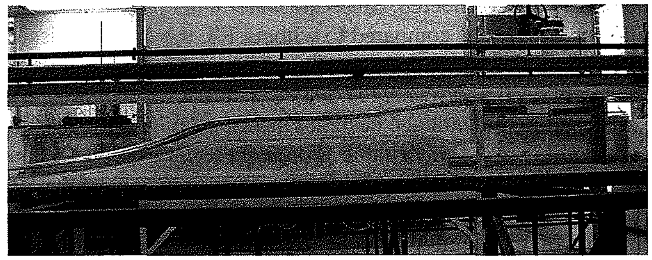

Fig. 1. Overflow above a broad-crested weir with rounded upstream edge with flow conditions $H_1/w=0.155$, $w=0.42$ m, and $P=0.0646$ m (flow from right to left)

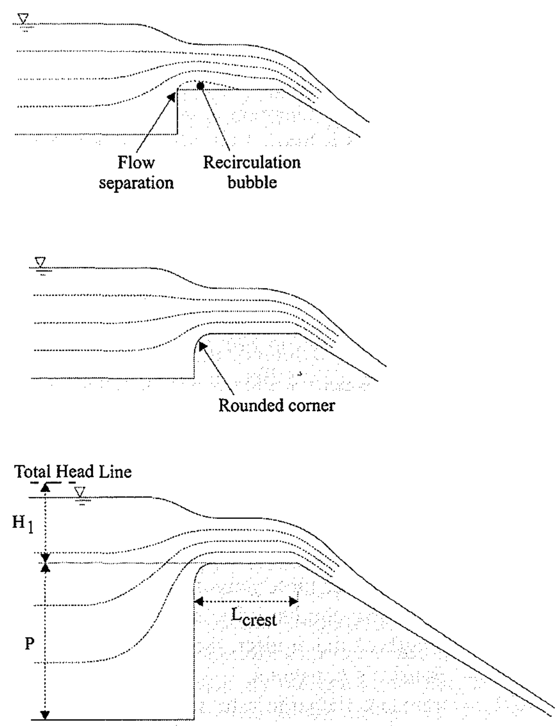

Fig. 2. Flow pattern above a rectangular broad-crested weir with vertical upstream wall: Effect of corner rounding and weir height on the streamline pattern

Table 1. Experimental Studies of Rectangular Broad-Crested Weir with Vertical Upstream Wall

Reference	Configuration	Geometry	P m	b m	w m
Bazin (1896)	Run 115	Square edge	0.75	2.0	0.80
	Run 116	Rounded (r=0.10 m)	0.75	2.0	0.90
Gonzalez and Chanson (2007)	Geometry 4	Rounded (r=0.06 m)	0.99	1.0	0.62
	Small weir	Rounded (r=0.028 m)	0.0646	0.25	0.42
Sargison and Percy (2009)	VRB	Square edge	0.25	0.30	0.50

Notes: b=rectangular channel width; P=weir height above the channel invert; r=upstream edge radius; w=broad-crested weir length.

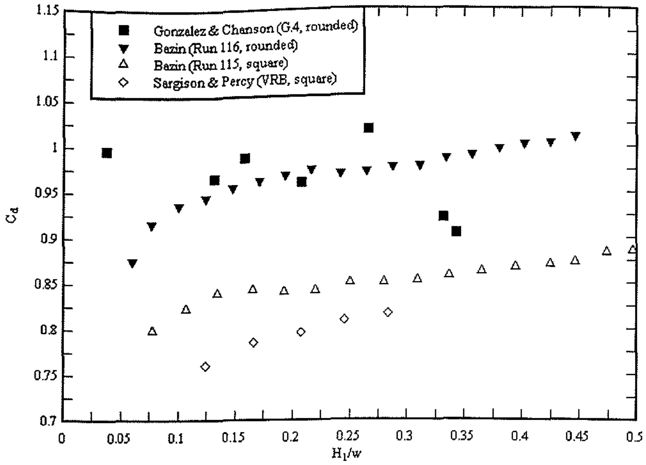

Fig. 3. Dimensionless discharge coefficient of rectangular broad-crested weirs with vertical upstream wall: Experimental data by Bazin (1896), Gonzalez and Chanson (2007), and Sarginson and Percy (2009)

head above crest. With a square-edged upstream corner, separation takes place immediately downstream and a recirculation bubble develops (Mos 1972).

Experimental data demonstrated uni-equivocally that the discharge capacity of square edge weirs was lesser than that of weirs designed with a rounded upstream corner for an identical upstream head above crest (Bos 1976). This is illustrated in Fig. 3 for which the details of the data sets are summarized in Table 1 (Bazin 1896; Gonzalez and Chanson 2007; Sargison and Percy 2009). Fig. 3 shows that the dimensionless discharge coefficient above broad-crested weirs with square-edged upstream corner (white symbols) ranged from 0.76 to 0.88 that are close to Mos's (1972) theoretical prediction of 0.87. With a rounded upstream corner, the dimensionless discharge coefficient of broad-crested weirs was in average 0.967 (Fig. 3, black symbols). For comparison and completeness, C_d was in average 0.88 and 0.92 with the 1H:1V and 2H:1V upstream slopes, respectively (Sargison and Percy 2009). In Fig. 3, note that the weir crest stops to act as a broad-crested weir for $H_1/L_{\text{crest}} > 0.3$ to 0.2 (Montes 1998), while an undular flow is observed above the weir crest for $H_1/L_{\text{crest}} < 0.1$ typically (Chanson 1996).

In summary, the upstream weir design has a significant effect on the discharge characteristics of broad-crested weirs. In the case of an upstream vertical wall, the optimum design includes a rounded upstream corner (Harrison 1967; Bos 1976; Montes 1998). An upstream side slope may provide an alternative design for embankment structure although with a lower discharge coefficient (Sargison and Percy 2009).

References

Bazin, H. (1896). "Expériences Nouvelles sur l'Ecoulement par Déversoir." ("Recent experiments on the flow of water over weirs.") Mémoires et Documents, Annales des Ponts et Chaussées, Séries 7, 12(2), 645–731 (in French).

Bélanger, J. B. (1841). "Notes sur l'Hydraulique." ("Notes on hydraulic engineering.") *Ecole Royale des Ponts et Chaussées*, Paris, France, session 1841–1842 (in French).

Bos, M. G. (1976). "Discharge measurement structures." *Publication No. 161*, Delft Hydraulic Laboratory, Delft, The Netherlands (also Publication No. 20, ILRI, Wageningen, The Netherlands).

Chanson, H. (1996). "Free-surface flows with near-critical flow conditions." *Can. J. Civ. Eng.*, 23(6), 1272–1284.

Chanson, H. (2004). *The hydraulics of open channel flows: An introduction*, 2nd Ed., Butterworth-Heinemann, Oxford, U.K.

Gonzalez, C. A., and Chanson, H. (2007). "Experimental measurements of velocity and pressure distribution on a large broad-crested weir." *Flow Meas. Instrum.*, 18(3–4), 107–113.

Harrison, A. J. M. (1967). "The streamlined broad-crested weir." *Proc., Instn. Civil Engrs.*, Institute of Civil Engineers, London, Vol. 38, 657–678.

Henderson, F. M. (1966). *Open channel flow*, Macmillan, New York.

Isaacs, L. T. (1981). "Effects of laminar boundary layer on a model broad-crested weir." *Research Report No. CE28*, Dept. of Civil Eng., Univ. of Queensland, Brisbane, Australia.

Jaeger, C. (1956). *Engineering fluid mechanics*, Blackie and Son, Glasgow, U.K.

Montes, J. S. (1998). *Hydraulics of open channel flow*, ASCE, New York.

Mos, W. D. (1972). "Flow separation at the upstream edge of a square-edged broad-crested weir." *J. Fluid Mech.*, 52(2), 307–320.

Sargison, J. E., and Percy, A. (2009). "Hydraulics of broad-crested weirs with varying side slopes." *J. Irrig. Drain. Eng.*, 135(1), 115–118.