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Discussion of "Energy and Momentum Velocity Coefficients for Calibrating Submerged Sluice Gates in Irrigation Canals" by Oscar Castro-Orgaz, David Lozano, and Luciano Mateos

September 2010, Vol. 136, No. 9, pp. 610–616.
DOI: 10.1061/(ASCE)IR.1943-4774.0000233.

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The authors have developed an interesting method in which velocity and momentum correction factors are introduced to the relations for sluice gates. The discussers present some comments on the subject and propose an alternative approach to the problem.

The authors present a modified form of the energy and momentum equations in which the Coriolis (α) and Boussinesq (β) coefficients are introduced. These correction coefficients are applied to account for the nonuniform velocity profile. In the original paper, the velocity head term in the energy equation [Eq. (5)] and the momentum flux term in the momentum equation [Eq. (6)] are written in terms of y, the total depth downstream of the gate, instead of y_2, the depth of the vena contracta where the kinetic energy and momentum flux are concentrated. Given that the velocities in the roller region are much smaller than those in the forward flow region of the vena contracta, using the total depth in the equations results in large values for α and β. In Fig. 2 of the original paper, three velocity profiles are shown for which α and β are as large as 14.93 and 4.56, respectively, whereas the values α and β for turbulent open-channel flows are found to rarely exceed 1.36 and 1.12, respectively (Chow 1959). The values in their Fig. 2 are much larger than the typical ones because of the fact that the flow reverses direction in the recirculating region. The form of Eqs. (5) and (6) in the original paper results in very large values for α and β, especially for deeply submerged gates. In Fig. 3(a) of the original paper, values of α as large as 110 are predicted, and the authors point out that for large submergences, there are large discrepancies between the standard energy-momentum (E-M) method and their proposed method. The coefficients α and β used in Eqs. (5) and (6) in the original paper may be used as calibration parameters despite the fact that they are defined differently from the conventional Coriolis and Boussinesq coefficients.

The sketch of the velocity profile shown in Fig. 1 in the original paper is not an accurate representation of the velocity distribution that occurs at the vena contracta. The vena contracta is located at a distance of approximately 1.15 times the gate opening downstream from the gate (Rajaratnam and Subramanya 1967b), and the flow does not have the opportunity to develop in this short length. As a result, the velocity profile at the vena contracta consists of a thin boundary layer and a thick potential core in which the velocity is almost uniform (Rajaratnam and Subramanya 1967b). The profiles plotted in Fig. 2 of the original paper were measured at distances of 5.15, 8.23, and 11.31 times the gate opening downstream from the gate, respectively (Oosterholt 1949). The shape of these velocity profiles indicates that the flow has developed considerably at these locations. For example, in Fig. 2(c) of the original paper, the forward flow includes 65% of the depth. Eqs. (5) and (6) of the original paper are written between the vena contracta (Section 2) and upstream (Section 1) and downstream (Section 3). The velocity profiles in the original papers Fig. 2 are at sections considerably downstream of the vena contracta where the profiles are almost developed [compare these profiles with the ones in Fig. 2 of Rajaratnam and Subramanya (1967b)], and therefore, the values of α and β obtained from these profiles should not be used for calibration.

Using y_2 as the depth in the velocity head and momentum flux terms provides the conventional form of the energy and momentum equations; i.e.,

$$y_1 + \frac{q^2}{2gy_1^2} = y + \alpha' \frac{q^2}{2gy_2^2} \tag{1}$$

$$\frac{y^2}{2} + \beta' \frac{q^2}{gy_2} = \frac{y_3^2}{2} + \frac{q^2}{gy_3} \tag{2}$$

where

$$\alpha' = \int_0^1 \left(\frac{u}{U}\right)^3 d(n/y_2) \tag{3}$$

$$\beta' = \int_0^1 \left(\frac{u}{U}\right)^2 d(n/y_2) \tag{4}$$

The values of α' and β' are expected to be in the common practical range. For the case of a submerged sluice gate, these coefficients were found to be close to unity (Naudascher 1991; Rajaratnam and Subramanya 1967a).

From a practical point of view, it is more convenient to include only one calibration parameter. Such a parameter, comprising the energy loss between the upstream and vena contracta sections, was introduced by Habibzadeh et al. (2011). The energy loss caused by the turbulence production in the large eddy near the water surface on the upstream side of the gate was represented by an energy-loss coefficient (ϵ) multiplied by the velocity head at the vena contracta.

J. Irrig. Drain Eng. 2012.138:855-856.