Role of Energy Loss on Discharge Characteristics of Sluice Gates

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Abstract: A theoretical method was used to derive an equation for the discharge coefficient of sluice gates in rectangular channels under orifice-flow (both free and submerged) conditions. The proposed equation allows for the effects of energy dissipation between the upstream section of the gate and the vena contracta. The hydraulic energy loss in the upstream pool is attributable to the induced turbulence by the recirculating region and to the growth of bottom boundary layer. For the submerged-flow condition, turbulent shear-layer entrainment is also responsible for the energy loss. This energy loss is introduced into the equations through a coefficient k that has been conventionally assumed to be negligible. Experimental data from the literature were used to validate the equation, which showed good agreement with the measured values. It is also shown that the magnitude of the energy-loss factor is a function of the geometry of the gate and can modify the discharge coefficient. An equation for the distinguishing condition between free and submerged flows is also presented. The new equations can be used to predict the performance of sluice gates with different edge shapes under free- and submerged-flow situations. **DOI: 10.1061/(ASCE)HY.1943-7900.0000406.**

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Introduction

Sluice gates are widely used in irrigation networks for flow control and measurement. The flow from the gate could be either free or submerged by the tailwater. The diffusion of a submerged jet downstream of a sluice gate has been studied by Henry (1950). He developed a relation between the discharge coefficient of the gate and the upstream head assuming hydrostatic pressure distribution and uniform velocity distribution at the upstream approach section and vena contracta and neglecting any energy loss between these two sections. He also developed a useful diagram for the discharge coefficient.

Rajaratnam and Subramanya (1967a) showed that for submerged flow, if the supercritical stream downstream of a sharp-edged sluice gate is defined as the one having the same discharge as the initial discharge at the gate opening, this stream reaches its minimum depth of 0.61 b (where b is the gate opening) at a distance of about 1.15 b. The pressure distribution was also found to be somewhat different from the hydrostatic one. In later research, Rajaratnam and Subramanya (1967b) studied free and submerged flow downstream of a vertical sluice gate. Their theoretical approach resulted in an equation common to both free and submerged flows, provided the value of the velocity distribution correction coefficient (Coriolis) is assumed to be unity. The value of the contraction coefficient (ratio of the depth at the vena contracta to the gate opening) was fixed at $C_c = 0.61$ on the basis of an earlier study on submerged flows by the authors (Rajaratnam and Subramanya 1967a). A practical value of $C_c = 0.61$ was previously recommended by Henderson (1966) for free flows. Swamee (1992) presented equations for free and submerged flows, as well as the criterion for a free-flow condition based on the experimental curves of Henry (1950).

Submerged radial gates were studied by Clemens et al. (2003). A correction factor was introduced to the energy equation to account for head loss, which was found to depend on Reynolds number. However, a value of 1.01 to 1.02 was suggested for field scale gates. Sepulveda et al. (2009) studied different calibration methods for the discharge coefficient of submerged sluice gates. They found that use of a constant contraction coefficient of 0.611, along with a theoretical formulation, gives good results within the practical range. However, they suggested that if discharge data from the field are available, the method presented by Ferro (2000, 2001) and Ansar (2001) is the best choice with errors not more than 3% within the studied range. They found that the equation presented by Swamee (1992) results in poor predictions. The contraction coefficient under free and submerged sluice gates was studied by Belaud et al. (2009). An analytical method was used to estimate the pressure force on the gate, and the results were used to evaluate the contraction coefficient along with the principle of momentum conservation and energy equation. A correction factor was used to account for kinetic energy and pressure variations as well as head loss. The energy loss was attributed to friction in the boundary layer and also the energy transferred to turbulence through large-scale turbulence structures; e.g., corner vortices and eddies. The equations for the contraction coefficient were used to estimate discharge and the results were compared with experimental data, as well as some relations found in literature. Lozano et al. (2009) studied sluice gates in irrigation canals under submerged conditions.

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