Hydraulic Engineering and Infrastructures

Civil Engineering Department

Hydraulic Structures

1 Free and submerged flow through a vertical sluice gate

We will use the notation and theoretical background presented in the Gates and Hydraulic Jumps notes available on Moodle.

This exercise concerns flow under a vertical sluice gate in a horizontal, rectangular channel of width b. Upstream of the gate the water depth is uniform and given by y_1. The gate opening is a, and due to contraction the jet thickness at the vena contracta is

$$y_g = C_c\, a,$$

where C_c is the contraction coefficient. The downstream uniform depth is denoted y_d (tailwater depth). We consider two operating regimes: free flow and submerged flow.

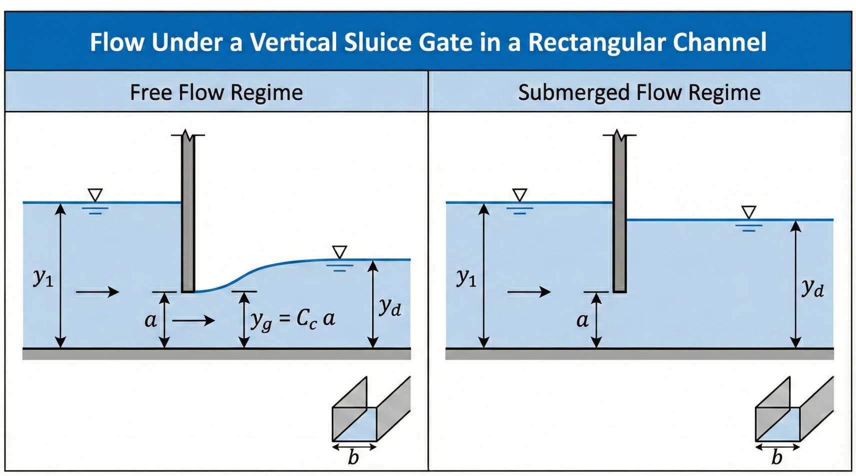

Figure 1: Free and submerged flow under a vertical sluice gate, showing upstream depth y_1, gate opening a, contracted jet thickness $y_g = C_c a$, and tailwater depth y_d.

Consider a sluice gate with geometric opening $a = 0.10$ m in a rectangular channel of width $b = 1.5$ m. Upstream depth is $y_1 = 1.0$ m, and the contraction coefficient is $C_c = 0.61$. Take $g = 9.81$ m/s^2.

(i) Using conservation of specific energy between the upstream section and the vena contracta, show that the free-flow discharge under the gate may be expressed as

$$Q_{\text{free}} = C_d\, b\, a\, \sqrt{2gy_1}, \qquad \text{with} \qquad C_d = \frac{C_c}{\sqrt{1 + \dfrac{C_c a}{y_1}}}.$$

Start by writing the specific energy at the upstream depth y_1 and at the contracted jet thickness $y_g = C_c a$, then set $E_1 = E_g$ to eliminate q. Show that this leads to the expression above for the discharge coefficient C_d. Finally, evaluate y_g and C_d numerically for the given data.

(ii) Compute the free discharge Q_{free} through the gate.

(iii) Determine the tailwater depth $y_{d,\text{crit}}$ for which the hydraulic jump would attach to the gate and compare it with y_1.

2 Ogee Spillway Design

A high overflow spillway with $P/H_d > 1.5$ has a maximum discharge of $283.2\,\mathrm{m}^3$/s with a maximum expected head of $6.10\,\mathrm{m}$. Using the USBR recommendation for the under-design procedure mentioned in class, determine the design head, spillway crest length (neglect contractions), and the minimum pressure (expressed in kPa) on the spillway. Plot the complete spillway crest shape for a compound circular curve in the upstream quadrant of the crest.