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Experimental Study of Flow Characteristics Beneath Sluice Gates with Cylindrical and Semi-Cylindrical Edges

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1- Introduction

Sluice gates are widely used for flow control and measurement in irrigation networks. Sharp edged sluice gates and radial gates have special characteristics that can be combined to make a new gate with satisfactory performance.

In the present research study, sluice gates with cylindrical and semi-cylindrical edges are introduced which enhances the contraction ratio and discharge coefficient of sluice gates. The gate operates just like sharp-edged sluice gates while a cylinder or semi-cylinder is attached to the edge of the gate (Fig. 1). In this paper, the flow characteristics of this cylindrical edged sluice gate including contraction coefficient, and curves for distinguishing free and submergence regimes are investigated. The best cylinder diameter is also determined for different flow conditions.

2- Methodology

Dimensional analysis is a useful tool in a better understanding of a phenomenon affected by some physical parameters. It is often used in deduction of equations and forming logical hypotheses about a complex physical issue.

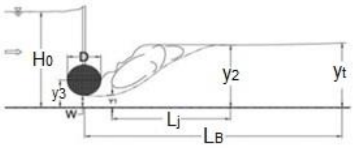

Fig. 1. Demonstration of the related parameters in cylindrical edged sluice gates in free and submergence conditions

The effective parameters can be categorized as fluid characteristics parameters, i.e., water density (ρ), dynamic viscosity (μ); flow parameters including water downstream of the gate (H_0), depth of the contracted supercritical flow downstream of the gate (y_1), conjugated hydraulic jump (y_2), tailwater depth (y_t), depth of submerged flow condition downstream of the gate (y_3), flow velocity in contracted section (V_1) or the flow rate (Q), gravity acceleration (g); and parameters related to channel geometry including cylinder diameter (D), the channel width (b), sluice gate opening (w) and channel cross-section geometry (C.G.). Therefore,

$$F(\rho, \nu, y_1, y_3, y_t, y_2, D, H_0, g, V_1, b, L_B, w, C.G) = 0 \qquad (1)$$

Considering the fact that the channel's width (b) and channel cross-section geometry (C.G.) are constant in all the experiments, the effect of these parameters can be ignored and Eq. (1) becomes:

$$F(\rho, \nu, y_1, y_3, y_t, y_2, g, V_1, L_B, w, D, H_0) = 0 \qquad (2)$$

Thus, the following dimensionless parameters are obtained.

$$\pi_1 = \frac{y_t}{w}, \pi_2 = \frac{y_3}{w}, \pi_3 = \frac{D}{w}, \pi_4 = \frac{y_2}{w}, \\ \pi_5 = \frac{L_B}{w}, \pi_6 = \frac{y_1}{w}, \pi_7 = \frac{H_0}{w}, \pi_8 = \mathrm{Re}_1, \pi_9 = Fr_1 \qquad (3)$$

These dimensionless parameters are combined together and new dimensionless parameters are formed.

3- Results

Figures 2 and 3 demonstrate the flow distinguishing curve and the contraction coefficient for the semi-cylindrical edged gates in comparison to the sharp-edged gate. The cylinder and semi-cylinder gates showed similar results regarding submerging depth. The distinguishing curve for the gates with 63, 90 and 125 mm semi-cylinder diameter edges shows marginal differences that can be because of insignificant differences in these three gates contraction coefficients. As shown in Figure 3, for H_0/W ranging from 4 to 18, the $Y_{t\ (max)}/W$ value for 63 mm diameter semi-cylindrical edged gate increased by 16% and for 90, 125 and 200 mm increased by 22% compared with the sharp-edge gate. It shows that the contraction coefficient has been increased for cylindrical edged gate considerably.

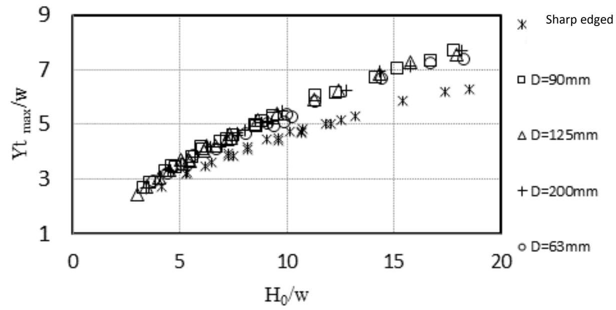

Fig. 2 Flow distinguishing curve for the semi-cylindrical edged compared with the sharp edged gate

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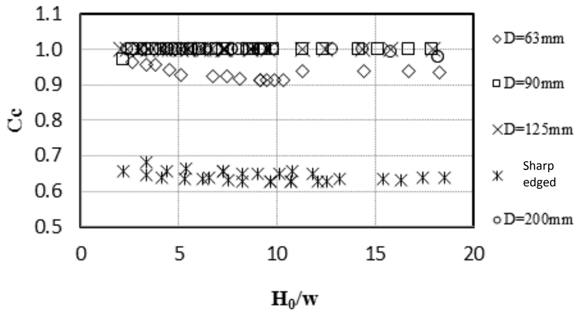

Fig.3- Contraction coefficient variation in the semi-cylindrical edged gates compared to the sharp edged gate

Figure 4 demonstrates the contraction coefficient variation for the cylindrical-edged gates versus cylinder diameter to upstream depth ratio. Experimental data from 63, 90, 125 and 200 mm cylinder diameter sluice gates for different amounts of upstream depth has been shown in this Figure. As can be seen, for cylinder diameter to upstream depth of up to 0.4, the contraction coefficient varies significantly and remains nearly equal to one thereafter. On the other hand, with a D/H_0 of 0.4, the contraction was not observed after the gate and the discharge capacity reached its maximum in the free flow condition. In other words, to reach a contraction coefficient equal to one, the cylinder's diameter should be at least equal to $0.4H_0$.

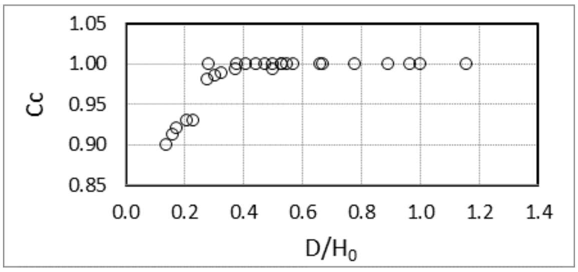

Fig.4 Contraction coefficient variations against the ratio of cylinder diameter to upstream depth for cylindrical edged gates

4- Conclusion

In this research, the contraction coefficient and distinguishing curves for cylindrical and semi-cylindrical edged sluice gates were studied. The results showed that by changing the shape of the gate edge, the contraction coefficient would change that results in the distinguishing flow curve. For gates with 90 mm cylinder diameter and more, the contraction coefficient is unity. This means that these gates can undergo more tail water depth while the free flow has been established. Such a condition is an important advantage for these kinds of gates since by preventing the submergence flow; it prevents an increase in the upstream depth and decreases the possibility of overflowing in the upstream part of the gate.