DEPARTMENT OF CIVIL ENGINEERING
Khulna University of Engineering & Technology, KHULNA

Expt No. : **1**

Name of the Experiment: **FLOW BENEATH A SLUICE GATE**

Apparatus:
i) Multipurpose Tilting Flume
ii) Sluice Gate
iii) Stop Watch

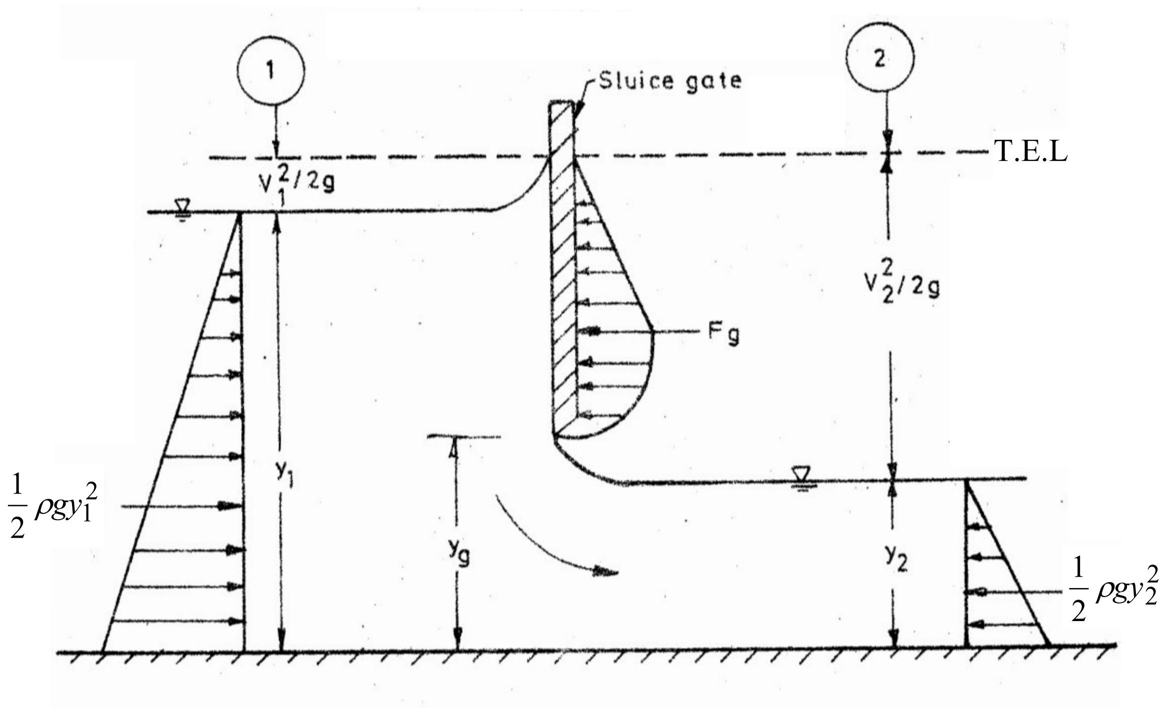

Fig. 1 Flow beneath a sluice gate

1. THEORY

The Bernoulli energy equation may be applied in those cases where there is a negligible loss of total head from one section to another, or where the magnitude of the head loss is already known. Flow under a sluice gate is an example of converging flow where the correct form of the equation for discharge may be obtained by equating the energies at Sections 1 and 2 as shown in the **Fig. 1**, as the energy loss between these sections is negligible.

$$H_1 = H_2 \tag{1}$$

and, therefore,

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \tag{2}$$

Expressing the velocities in terms of Q, the above equation becomes

$$y_1 + \frac{Q^2}{2gb^2 y_1^2} = y_2 + \frac{Q^2}{2gb^2 y_2^2} \tag{3}$$

where, b is the width of the sluice gate.

Simplifying and re-arranging the terms, one obtains

$$Q = by_1 \sqrt{\frac{2gy_1}{\frac{y_1}{y_2} + 1}} \tag{4}$$

or alternatively
$$Q = by_2 \sqrt{\frac{2gy_1}{\frac{y_2}{y_1} + 1}} \tag{5}$$

The small reduction in flow velocity due to viscous resistance between Sections 1 and 2 may be allowed for by a coefficient C_v. Then

$$Q = C_v b y_2 \sqrt{\frac{2gy_1}{\frac{y_2}{y_1} + 1}} \tag{6}$$

The coefficient of velocity, C_v varies in the range $0.95 < C_v < 1.0$, depending on the geometry of the flow pattern (expressed by the ratio y_g/y_1) and friction.

The downstream depth y_2 may be expressed as a function of the gate opening, y_g, i.e.

$$y_2 = C_c\, y_g \tag{7}$$

where, C_c is the coefficient of contraction whose commonly accepted value of 0.61 is nearly independent of the ratio y_g/y_1.The maximum contraction of the jet occurs approximately at a distance equal to the gate opening. Thus, Eq.(6) becomes

$$Q = C_c C_v b y_g \sqrt{\frac{2gy_1}{\frac{C_c y_g}{y_1} + 1}} \tag{8}$$

The above equation can also be written as

$$Q = C_d b y_g \sqrt{2gy_1} \tag{9}$$

where, C_d is the coefficient of discharge and is a function of C_v, C_c, b, y_g and y_1.

Therefore,
$$C_d = \frac{C_c C_v}{\sqrt{C_c y_g / y_1 + 1}} \tag{10}$$

Equation (9) may also be written as

$$Q_a = C_d Q_t \tag{11}$$

so that
$$Q_t = b y_g \sqrt{2gy_1} \tag{12}$$

where, Q_t and Q_a are the theoretical and actual discharges, respectively.

The momentum equation may be applied to the fluid within any chosen control volume where the external forces are known or can be estimated to a sufficient degree of accuracy. The horizontal components of these forces acting on the fluid within the control volume shown in **Fig. 1** are the resultants of the hydrostatic pressure distributions at Sections 1 and 2, the viscous shear force on the bed and the thrust of the gate. It should be noted that the equation permits the resultant gate thrust (F_g) to be determined even though the pressure distribution along its surface is not hydrostatic. Over a short length of smooth bed the contribution of the shear force may he neglected. The resultant force applied to the fluid within the control volume in the downstream direction is given by

$$F_x = \left[\frac{1}{2}\rho g y_1^2 - \frac{1}{2}\rho g y_2^2 - F_g\right] b \tag{13}$$

The effect of this force is to accelerate the fluid within the control volume in the downstream direction. Hence,

$$F_x = \rho Q_a (V_2 - V_1) \tag{14}$$

Substituting for F_x and gathering terms, one obtains

$$F_g = \frac{1}{2}\rho g y_2^2\left[\left(\frac{y_1}{y_2}\right)^3 - 1\right] - \frac{\rho Q_a^2}{b^2 y_2}\left[1 - \frac{y_2}{y_1}\right] \tag{15}$$

Simplifying and eliminating Q_a, we get

$$F_g = \frac{1}{2}\rho g \frac{(y_1 - y_2)^3}{y_1 + y_2} \tag{16}$$

The pressure distribution on the gate cannot he hydrostatic, as the pressure must be atmospheric at both the upstream water level and at tile point where the jet springs clear of the gate.

Note that the thrust on the gate, F_H, for a hydrostatic pressure distribution is given by

$$F_H = \frac{1}{2}\rho g (y_1 - y_g)^2 \tag{17}$$

2. OBJECTIVES

i. To determine the discharge beneath the sluice gate.

ii. To determine C_v, C_c, and C_d.

iii. To plot C_c and C_d vs. y_g/y_1 in plain graph paper.

iv. To plot y_1 vs. Q_a for different y_g in plain graph paper.

3. ASSIGNMENTS

i. Explain why the pressure distribution along the surface of the gate is not hydrostatic.

ii. What happens when the gate opening is greater than the critical depth?

iii. Verify Equations (9) and (16).

iv. When does the submergence occur and what is its effect on the flow beneath a sluice gate?

4. DISCUSSION

Comment on the results obtained, sources of error, etc.

Flow beneath a Sluice Gate

Experimental Data Sheet

Width of Channel, b = ______________ cm

No. of obs.	y_g (cm)	y_1 (cm)	y_2 (cm)	Volume of Water (Lit)	Time (sec)	Actual Discharge Q_a (m^3/s)	Theoretical Discharge Q_t (m^3/s)	C_d	C_c	C_v

Name of Student : ____

Roll No.: ________________ Group No.: ______________ ________________

Signature of Teacher

Date : ________________