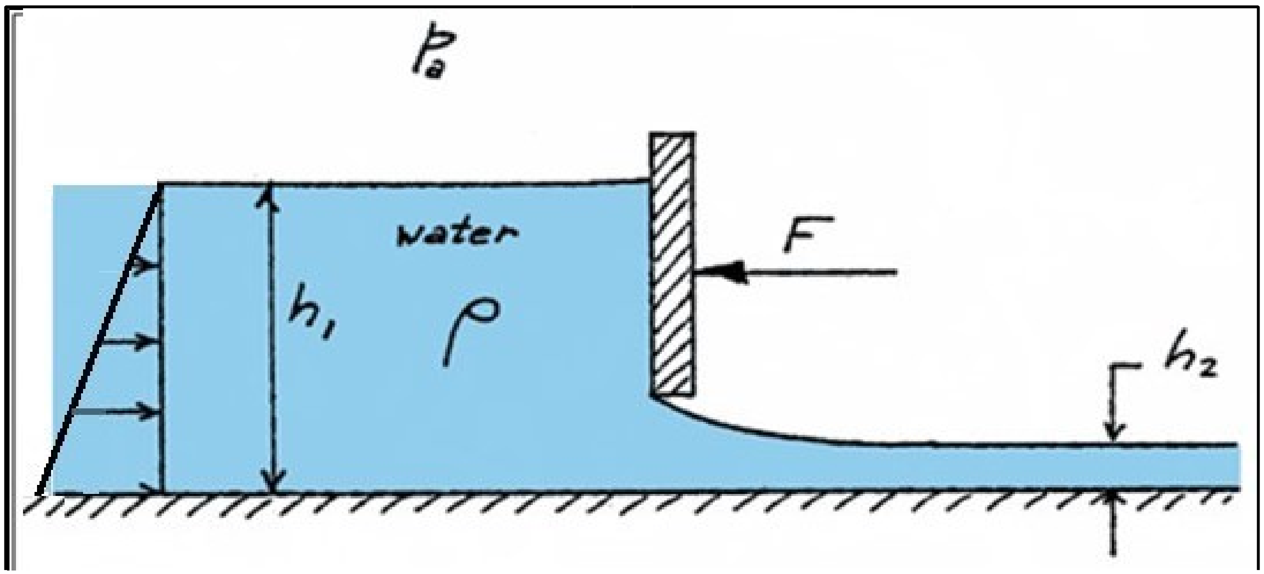
Experiment No. 4

FLOW BENEATH A SLUICE GATE



6.1 General

- ❖ Sluice gate is a classical example of the application energy and momentum principle.
- ❖Sluice gate is used in open channel to control and regulate the flow as well as to measure the discharge in the channel.
- ❖Sometimes it is used to raise the water level and maintain a constant operating level in irrigation canals.
- ❖Sluice gate is also used for draining the excess water for both urban areas and rural agricultural areas.
- ❖This experiment deals with the measurement of discharge beneath a sluice gate.

6.2 Theory

6.2.1 Description of the sluice gate

The simple form of a sluice gate consists of a horizontal channel bed having a vertical gate which can be lifted vertically up and down.

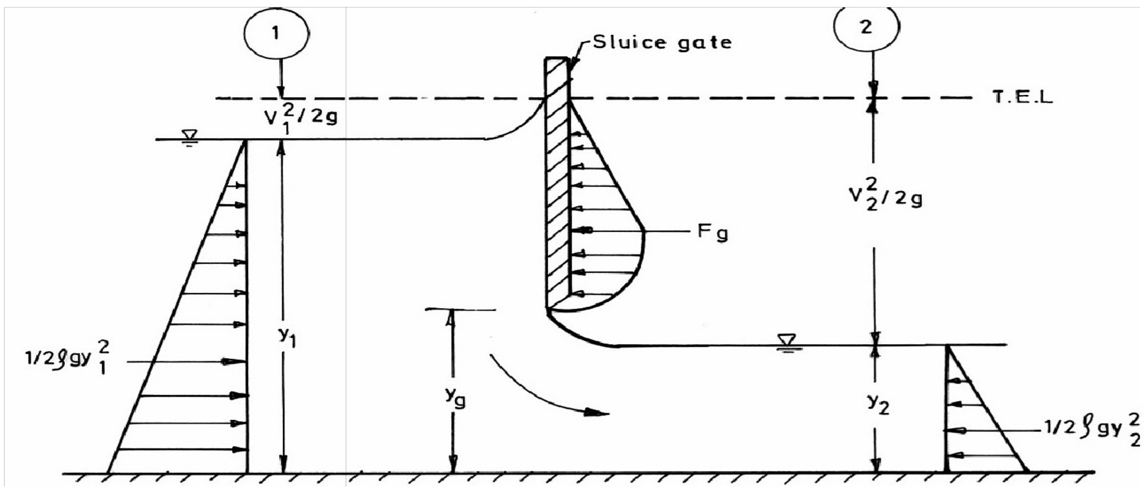


Fig. 6.1 Flow beneath a sluice gate

6.2.2 Theoretical discharge

- The Bernoulli 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 Fig. 6.1. As the energy loss between the sections is negligible, we have

$$H1 = H2 \qquad (6.1)$$

and therefore

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \qquad (6.2)$$

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

$$y_1 + \frac{Q^2}{2gb^2y_1^2} = y_2 + \frac{Q^2}{2gb^2y_2^2} \qquad (6.3)$$

Where, b is the width of the sluice gate. Simplifying and rearranging the terms, we obtain

$$Q = by_1\sqrt{\frac{2gy_2}{(y_1/y_2+1)}} \qquad (6.4)$$

or alternatively

$$Q = by_2\sqrt{\frac{2gy_1}{(y_2/y_1+1)}} \qquad (6.5)$$

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

$$Q = C_v by_2\sqrt{\frac{2gy_1}{(y_2/y_1+1)}} \qquad (6.6)$$

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.

$$y_2 = C_c y_g \qquad (6.7)$$

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.(6.6) becomes

$$Q = C_c C_v b y_g \sqrt{\frac{2 g y_1}{\left(C_c y_g / y_1 + 1\right)}} \qquad (6.8)$$

The above equation can also be written as

$$Q = C_d b y_g \sqrt{2 g y_1} \quad (6.9)$$

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

$$C_d = \frac{C_c C_v}{\sqrt{C_c y_g / y_1 + 1}} \quad (6.10)$$

Equation (6.9) may also be written as

$$Qa = CdQt \quad (6.11)$$

So that

$$Q_t = b y_g \sqrt{2 g y_1} \quad (6.12)$$

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

6.2.3 Forces on a sluice gate

- 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. 6.1 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 be neglected. The resultant force applied to the fluid within the control volume in the downstream direction is given by

$$F_x = \left[(1/2)\rho g y_1^2 - (1/2)\rho g y_2^2 - F_g\right] b \qquad (6.13)$$

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

$$F_x = \rho Q_a V_2 - \rho Q_a V_1 \qquad (6.14)$$

Substituting for F_x and gathering terms, we obtain

$$F_g = \frac{1}{2}\rho g y_2^2\left[(y_1 / y_2)^2 - 1\right] - \frac{\rho Q_a^2}{b^2 y_2}\left[1 - \frac{y_2}{y_1}\right] \qquad (6.15)$$

Simplifying and eliminating Q_a, we get

$$F_g = \frac{1}{2}\rho g \frac{(y_1 - y_2)^3}{y_1 + y_2} \qquad (6.16)$$

- The pressure distribution on the gate cannot be hydrostatic, as the pressure must be atmospheric at both the upstream water level and at the 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

$$F_H = \frac{1}{2}\rho g\left(y_1 - y_g\right)^2 \qquad (6.17)$$

6.3 Objectives

1. To determine the discharge beneath the sluice gate.

2. To determine C_v, C_c and C_d.

3. To plot $y_1$vsQ_a for different values of y_g in a plain graph paper.

4. To determine F_g and F_H and hence to find the ratio F_g/F_H.

6.4 Experimental setup

The experimental setup is given below.

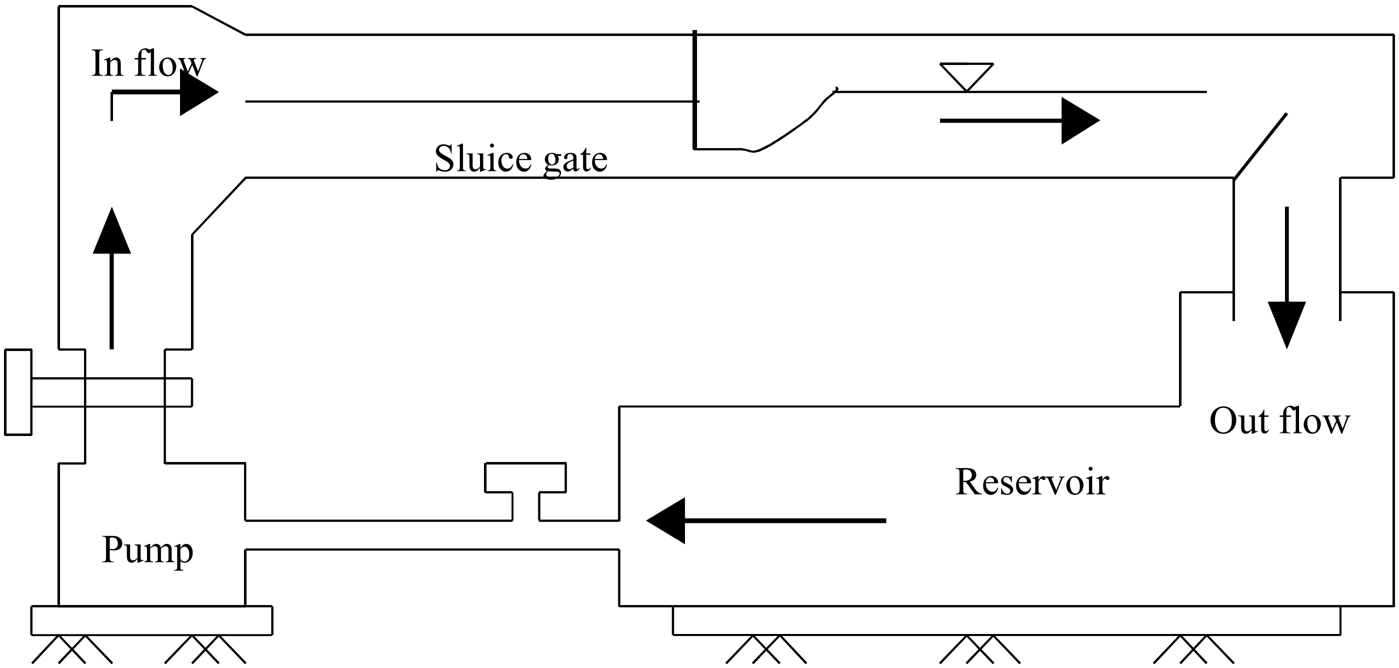


Fig. 6.2 Setup for flow beneath a sluice gate

6.4.1: Required apparatus:

a) Flume
b) Pump
c) Flow measuring unit
d) Reservoir
e) Water meter.
f) Sluice gate

6.5 Procedure

To determining the discharge beneath the sluice gate

1. Measure y_1 and y_g.
2. Calculate the theoretical discharge using Eq. (6.12).
3. Take the reading of actual discharge from the water meter.

To determine C_v, C_c and C_d

1. Calculate C_c using Eq.(6.7).
2. Using the value of C_c, calculate C_v using Eq.(6.8).
3. Using the values of C_c and C_v, determine C_d using Eq. (6.10).

Plot y_1 vs Q_a for different values of y_g in a plain graph paper.

To determine F_g and F_H and hence to find the ratio F_g/F_H

1. Determine y_2.
2. Determine F_g using Eq.(6.16).
3. Determine F_H using Eq.(6.17) and calculate the ratio F_g/F_H

6.6 Shape of y_1 vs Q_a graph

In a plain graph paper the plot of $Q_a = ky_1^n$ is a parabola. Now, if y_g increases, for same value of y_1, Q increases. So, the $y_1$vs Q_a graph for a higher value of y_g lies below the same graph for a lower value of y_g.

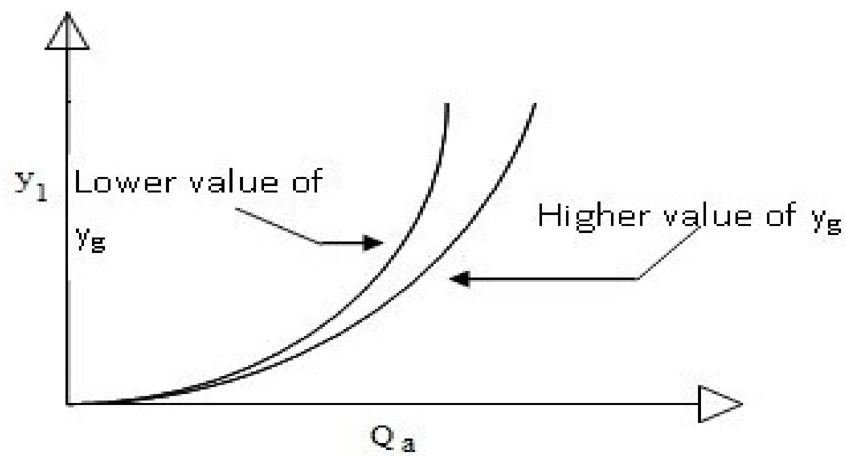


Fig. 6.3 Shape of $y_1$vs $Q_a$graph

6.7 Data sheet for example:

For Free Flow Condition:

Width of the sluice ate ,b = 7.7 cm

Sl No.	Yg	Y1	Y2	Qa	Qth	Cv	Cc	Cd	Fg	Fh	Yg/Y1	Fg/Fh
01	1.55	7.25	1.10	500								
02	1.55	9.60	1.10	600								
03	1.55	12.10	1.15	700								
04	1.55	15.00	1.15	800								
05	2.00	9.80	1.60	900								
06	2.00	11.20	1.60	1000								
07	2.00	13.50	1.60	1100								
08	2.00	17.50	1.85	1200								

6.7 Data sheet for example:

For submerged Flow Condition:

Sl No.	Yg	Y1	Y2	Qa	Qth	Cv	Cc	Cd	Fg	Fh	Yg/Y1	Fg/Fh
01	1.55	8.0	6.90	500								
02	1.55	11.0	7.70	600								
03	1.55	13.90	8.40	700								
04	1.55	16.10	9.00	800								
05	2.00	14.4	8.80	900								
06	2.00	12.5	9.20	1000								
07	2.00	15.5	10.10	1100								
08	2.80	19.4	11.18	1200								

6.8 Calculation

6.9 Results

6.10 discussion