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.

\[ H_1 = H_2 \]  
\[ y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \]  
\[ y_1 + \frac{Q^2}{2gb^2y_1^3} = y_2 + \frac{Q^2}{2gb^2y_2^3} \]  

where, \( b \) is the width of the sluice gate.

Simplifying and re-arranging the terms, one obtains

\[ Q = by_1 \sqrt{\frac{2gy_1}{y_1 + 1}} \]
or alternatively

\[ Q = by_2 \left( \frac{2gy_1}{y_2^2 + 1} \right) \]  

(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

\[ Q = C_v by_2 \left( \frac{2gy_1}{y_2^2 + 1} \right) \]  

(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 \( y_2/y_1 \)) and friction.

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

\[ y_2 = C_c y_g \]  

(7)

where, \( C_c \) is the coefficient of contraction whose commonly accepted value of 0.61 is nearly independent of the ratio \( y_2/y_1 \). The maximum contraction of the jet occurs approximately at a distance equal to the gate opening. Thus, Eq.(6) becomes

\[ Q = C_c C_v by_g \left( \frac{2gy_1}{C_c y_g + 1} \right) \]  

(8)

The above equation can also be written as

\[ Q = C_d by_g \sqrt{2gy_1} \]  

(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,

\[ C_d = \frac{C_v C_c}{\sqrt{C_c y_g / y_1 + 1}} \]  

(10)

Equation (9) may also be written as

\[ Q_a = C_d Q_t \]  

(11)

so that

\[ Q_t = by_g \sqrt{2gy_1} \]  

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

\[ F_x = \left[ \frac{1}{2} \rho gy_1^2 - \frac{1}{2} \rho gy_2^2 - F_g \right] b \]  

(13)
The effect of this force is to accelerate the fluid within the control volume in the downstream direction. Hence,

\[ F_x = \rho Q_a (V_2 - V_1) \]  

(14)

Substituting for \( F_x \) and gathering terms, one obtains

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

(15)

Simplifying and eliminating \( Q_a \), we get

\[ F_g = \frac{1}{2} \rho g \left( \frac{y_1 - y_2}{y_1 + y_2} \right)^3 \]  

(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

\[ F_H = \frac{1}{2} \rho g (y_1 - y_g)^2 \]  

(17)

2. OBJECTIVES

i. To determine the discharge beneath the sluice gate.

ii. To determine \( C_r \), \( C_c \), 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

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

Roll No.: __________  Group No.: __________  __________

Date: __________  

Signature of Teacher