

HL05 – Sluice gate flow and hydraulic jump analysis

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Introduction

A sluice gate is similar to an inverted sharp-crested weir. The sluice gate partially blocks the flow of water in a rectangular channel producing a subcritical flow upstream of the gate, while the flow downstream flow, uncontrolled, is supercritical. If supercritical flow can be achieved in the channel, placing stop logs at the channel exit may raise the water depth at the downstream end of the channel so that the flow becomes subcritical there. The transition from supercritical to subcritical flow takes place through a hydraulic jump. Figure 1 shows the CEE Hydraulics Laboratory's Teaching Flume fitted with a sluice gate and stop logs at the exit to produce a hydraulic jump. Details of the flow under the sluice gate are shown in Figure 2.

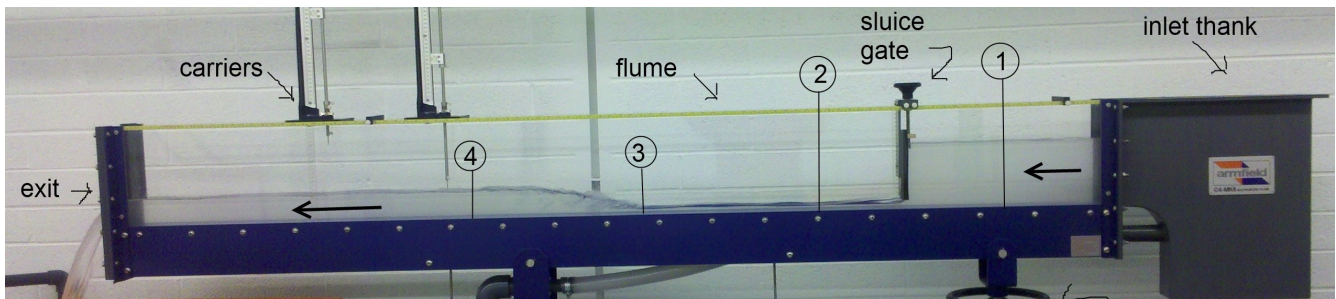


Figure 1. Picture of the C4-MKII-7 Armfield's Multipurpose Teaching Flume with a sluice gate

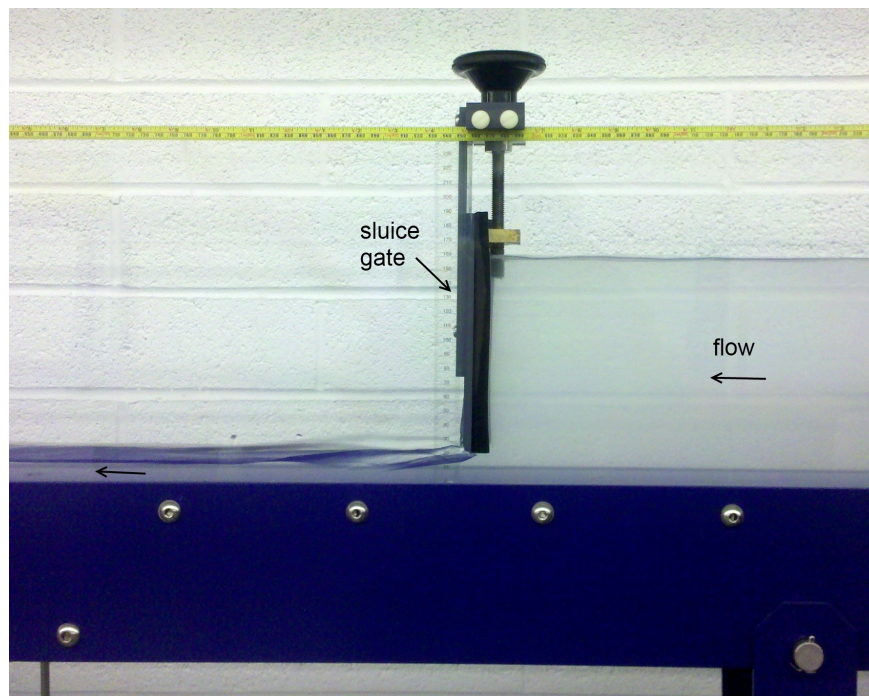


Figure 2. Details of flow under a sluice gate in the Teaching Flume.

For a set up as that shown in Figure 1 the analysis of the flow under the sluice gate requires measurement of the water depths upstream and downstream of the gate, i.e., in sections (1) and (2). The analysis of the hydraulic jump, on the other hand, would require measuring the depths in sections (3) and (4). The Hydraulic Bench can be used to calculate the discharge through the flume as in other Teaching Flume experiments.

Procedure

Set up the sluice gate about 1/3 of the distance down the flume from the inlet tank, and give it a small opening. Write down the gate opening.. Turn on the pump in the Hydraulic Bench attached to the Teaching Flume and adjust the discharge so that the depth upstream of the gate is about 0.20 m. Measure depths of flow upstream and downstream of the gate, and the discharge through the flume. Then, place stop logs at the channel exit until a hydraulic jump is produced in the flume. Measure the depths of flow upstream and downstream of the hydraulic jump.

Remove the stop logs, increase the gate opening and adjust the discharge to keep the depth upstream of the gate close to 0.20 m. Repeat the depth measurements, and the production of the hydraulic jump as indicated above. Continue opening the gate and repeating the test until completing 5 or 6 measurements.

The following table can be used to collect your data: Channel Width = _____ m

Test No.	Gate opening	Gate depths		Jump depths		Discharge measurement	
	b (m)	y1 (m)	y2 (m)	y3 (m)	y4 (m)	V(m ³)	t (sec)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Data analysis

Out of the data collected in the table in the previous page the following analysis can be produced.

1 – The discharge coefficient, C_d , for flow under the gate can be calculated from

$$Q = C_d \cdot W \cdot b \cdot \sqrt{2 \cdot g \cdot y_1}$$

2 – Specific energies upstream and downstream of the gate can be calculated using:

$$E_1 = y_1 + \frac{V_1^2}{2 \cdot g}, \text{ and } E_2 = y_2 + \frac{V_2^2}{2 \cdot g}$$

Compare these two energies to check whether energy is conserved across the gate.

3 – Use the momentum equation to obtain an expression for the force on the gate, F_g , based on the depths of flow upstream and downstream of the gate. The corresponding hydrostatic force would be

given by $F_h = \frac{1}{2} \cdot \rho \cdot g \cdot (y_1 - b)^2$.

4 – For the hydraulic jump calculate the momentum functions, $fm_3 = \frac{q^2}{g \cdot y_3} + \frac{y_3^2}{2}$, and

$fm_4 = \frac{q^2}{g \cdot y_4} + \frac{y_4^2}{2}$, here $q = \frac{Q}{b}$. Compare the values of the momentum functions and check whether momentum is conserved across the hydraulic jump.

5 – Verify the equations $\frac{y_3}{y_4} = \frac{1}{2} \left(-1 + \sqrt{1 + \frac{8 \cdot q^2}{g \cdot y_3^3}} \right)$, and $q = \sqrt{\frac{g \cdot y_3 \cdot y_4 \cdot (y_3 + y_4)}{2}}$.

6 – Calculate the energy drop through the jump, h_J .