HYDRAULICS 3: OPEN-CHANNEL FLOW LABORATORY

Part 1: Broad-Crested Weir
Part 2: Venturi Flume
Part 3: Gate

Notation

H	total head
h	water depth
z_s	water surface level
b	channel width
Q	discharge
q	discharge per unit width ($= Q/b$)
V	velocity
Fr	Froude number

Measurements

Open-channel flow simulations are conducted in the Armfield C4-MKII flume. Water is pumped and recirculated via the Armfield F1-10 hydraulics bench. A flow valve in the bench is used to regulate the discharge.

Water depth is determined by the difference between water-surface and bed levels measured by a point gauge. The undisturbed width of the flume may be measured with a ruler and the width at the venturi throat using internal calipers.

Flow rates are measured by timed collection in the measuring chamber of the hydraulics bench. A volume of 30 litres is suitable.

Use the handwheel and slope indicator below the flume to set the bed slope. Except where indicated in Part 3, the channel bed should be horizontal.

Results and Submission

Submit only the completed results sheet.

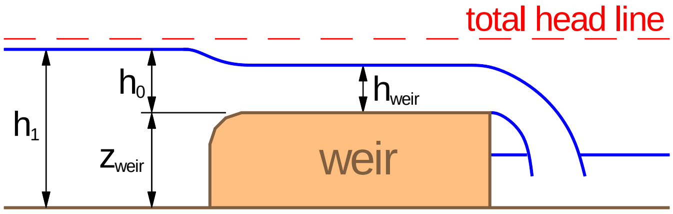
At the end of the lab, hand in the results sheet to the demonstrator.

Part 1: Broad-Crested Weir

<u>Objectives</u>

For a broad-crested weir:

- to observe the flow patterns associated with such a device;
- to examine the relationship between discharge and freeboard;
- to measure the discharge coefficient.



<u>Theory</u>

Assuming no loss of head,

$$H_{\text{weir}} = H_{\text{upstream}} \,, \qquad \text{where} \qquad H = z_s + \frac{V^2}{2g}$$

The critical depth is

$$h_c = \left(\frac{q^2}{g}\right)^{1/3} , \qquad \text{where} \qquad q = \frac{Q}{b} \qquad (1)$$

Measuring the vertical coordinate z from the top of the weir, the total head is

$$\underbrace{\frac{3}{2}\left(\frac{q^2}{g}\right)^{1/3}}_{H_{\text{weir}}} = \underbrace{h_0 + \frac{q^2}{2gh_1^2}}_{H_{\text{upstream}}}$$

h_0 is the freeboard and h_1 is the upstream depth. Rearrange for the discharge per unit width:

$$q = (2/3)^{3/2}\sqrt{g}(h_0 + \frac{q^2}{2gh_1^2})^{3/2}$$

or the total discharge $Q = qb$ (in metre-second units) by an iterative solution of

$$Q_{\text{ideal}} = 1.705b(h_0 + \frac{Q_{\text{ideal}}^2}{19.62b^2h_1^2})^{3/2} \qquad (2)$$

This gives an ideal value for the discharge. In practice, the *discharge coefficient* c_d is

$$c_d = \frac{\text{actual discharge}}{\text{ideal discharge}} = \frac{Q}{Q_{\text{ideal}}} \qquad (3)$$

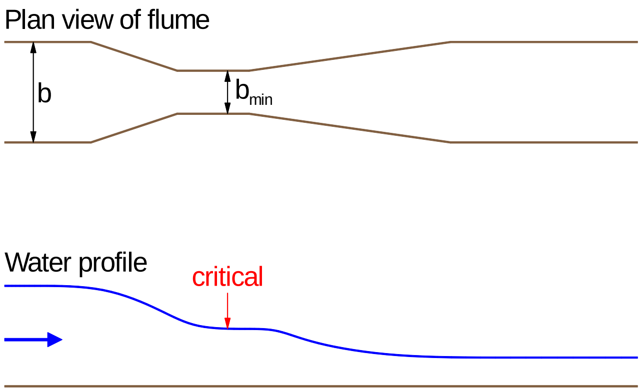
<u>Experiment</u>

Fix the broad-crested weir firmly at the upstream fixing point in the flume. (The curved end of the weir should face upstream.) Measure the width of the channel with a ruler. Using the point gauge, record levels for the bed of the channel and the top of the weir.

Adjust the flow valve in the hydraulics bench to allow at least two sets of measurements of:

h_1	upstream depth
h_0	freeboard
h_{weir}	depth over the weir
Q	discharge

Part 2: Venturi Flume



Objectives

- To demonstrate sub- to supercritical flow transition through a narrow section;
- to establish whether critical conditions occur in the throat;
- to determine whether fluid head is conserved through the device.

Theory

Assuming the flow to be choked (controlled by the width of the venturi) the flow undergoes a smooth transition from subcritical to supercritical flow through the restricted section. If the throat section is sufficiently long to establish parallel flow then critical conditions occur in the throat.

Velocity V can be determined from the discharge and the *local* flow cross-section:

$$V = \frac{\text{flow rate}}{\text{area}} = \frac{Q}{bh}$$

Note that, depending on location, b may be either the width of the main channel or the throat.

The Froude number and total head at any position are given by

$$\text{Fr} = \frac{V}{\sqrt{gh}}$$

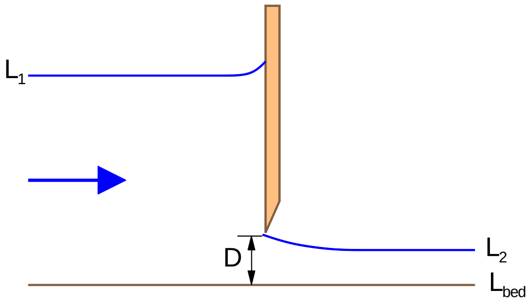
$$H = z_s + \frac{V^2}{2g}\ , \qquad \text{where} \qquad z_s = h$$

Experiment

Place the venturi flume assembly, including an appropriate spacer, in the Armfield C4-MKII flume. The venturi throat should be closer to the upstream end. Measure the undisturbed width of the flume and the width at the venturi throat with a ruler.

Adjust the flow valve in the Armfield F1-10 Hydraulics Bench to allow at least two different flow rates through the flume. For each flow rate measure water depths just upstream, in the throat (at the end of the parallel section) and just downstream of the flume, and measure the discharge by timed collection of water.

Part 3: Gate



Objective

- to observe the flow transition caused by such a device;
- to observe the effects of slope and of multiple control devices in a channel.

Experiment

With the broad-crested weir in place upstream, secure the gate near the downstream end of the flume. Adjust the gate opening to between 20 and 25 mm.

Turn the discharge to maximum and use a plate (or your hand) to hold up the water upstream of the gate briefly, so that the supercritical flow from the weir doesn't simply pass undisturbed below it. With a horizontal bed the gate will cause the flow to back up to the weir.

With a bed slope of 0º, sketch the water-surface profile along the whole length of the flume.

Using the handwheel, set a bed slope of about 2% and wait for the flow to settle. By adjusting the slope you should be able to re-establish supercritical flow for some distance downstream of the weir, with a hydraulic jump between weir and gate. Again, sketch the water-surface profile along the whole length of the flume.

In your sketches mark the regions of subcritical, critical and supercritical flow and the main control points.