EXPERIMENT B

Characteristics of flow over a Broad Crested Weir.

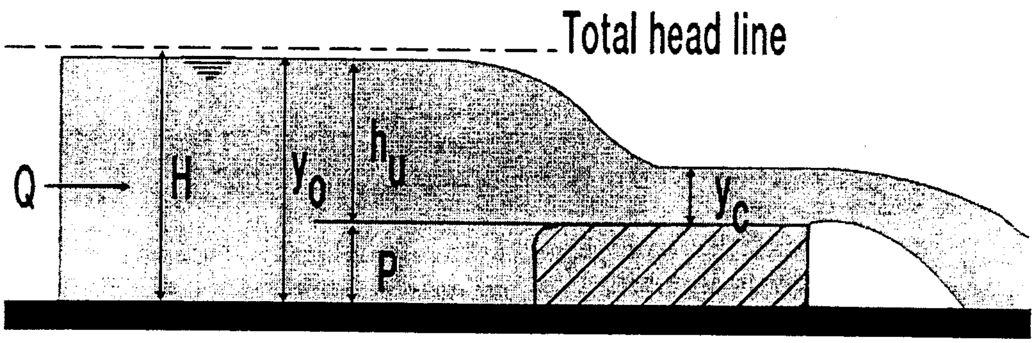
OBJECTIVE

To determine the relationship between upstream head and flowrate for water flowing over a Broad Crested weir (long base weir), to calculate the discharge coefficient and to observe the flow patterns obtained.

EQUIPMENT SET-UP

Multi-Purpose Teaching Flume C4

Broad Crested Weir
Hook and point gauge, 300mm scale – 2 required
Stopwatch if measuring flowrate using the volumetric tank (not supplied)



SUMMARY OF THEORY/BACKGROUND

Provided that the weir is not submerged (downstream water level is low) the actual flow over a Broad Crested weir is given by:

$$Q = 1.704\, C_d\, b\, H^{\frac{3}{2}} \quad \text{therefore:} \quad C_d = \frac{Q}{1.704\, b\, H^{\frac{3}{2}}}$$

where:

Q	= Volume flowrate	($m^3.s^{-1}$)
	= Volume/time (using volumetric tank)	
C_d	= Coefficient of discharge	(Dimensionless)
b	= Breadth of weir	(m)
H	= Total Head upstream of weir	(m)

$$= y_o + \frac{V^2}{2g} = y_o + \frac{Q^2}{2gA^2} = y_o + \frac{Q^2}{2g(y_o b)^2}$$

When using this type of weir in a real application it is more convenient to measure the head h_u upstream of the weir. The flow equation must be modified to take account of the velocity head component as follows:

$$Q = 1.704\, C_d\, C_v\, b\, h_u^{\frac{3}{2}}$$

Therefore $$C_v = \frac{Q}{1.704\, C_d\, b\, h_u^{\frac{3}{2}}}$$

where:

C_v	= Coefficient of velocity	(Dimensionless)
h_u	= Head above the weir crest (upstream)	(m)
	= Upstream depth of flow (y_0) – Height of weir	(P)

Note: The weir can be used for flow measurement using a single measurement of level upstream provided that a standing wave exists downstream of the weir. The condition at which the standing wave ceases is called the modular limit and is investigated in later experiments.

PROCEDURE

Ensure the flume is level, with no stop logs installed at the discharge end of the channel. Measure and record the actual breadth b (m) of the broad crested weir.

Install the weir in the flume with the rounded corner upstream. Ensure that the weir is secured using a mounting hook through the bed of the flume. For accurate results the gaps between the weir and the channel should be sealed on the upstream side using Plasticine. Position two hook and point level gauges on the channel sides, adjacent to the weir, each with the point fitted.

The datum for all measurements will be the bed of the flume. Carefully adjust the level gauges to coincide with the bed of the flume and record the datum readings. Using one level gauge carefully measure the height of the weir above the bed P (m) taking care not to damage the surface of the weir. Position this level gauge over the weir at the discharge end. Position the second level gauge some way upstream from the weir.

Adjust the flow of water into the flume to obtain heads h_u, increasing in about 0.010m steps. For each step measure the flowrate Q, the upstream depth of flow y_0 and the depth of flow over the weir y_c (where the flow becomes parallel to the weir). The flowrate Q can be determined using the direct reading flowmeter or the volumetric tank with a stopwatch. For accurate results the level gauge must be far enough upstream to be clear of the draw-down over the weir.

At each setting also observe and sketch the flow patterns over the weir.

Gradually increase the depth of the water downstream of the weir by adding stop logs at the discharge end of the channel, For each step measure the flowrate Q, the upstream depth of flow y_0 and the depth of flow over the weir y_c. Observe and sketch the flow patterns over the weir.

RESULTS AND CALCULATIONS

Tabulate your readings and calculations as follows:

Breadth of Weir b =...........(m)

Height of weir P =...........(m)

y_0	y_c	Q	$H^{3/2}$	C_d	$h_u^{3/2}$	C_v

Plot graphs of Q against H, log Q against log H and C_d against H.

From the straight-line graph of log Q against log H find the intercept log k on the log Q axis and the gradient m.

The relationship between Q and H is then $Q = k H^m$.

Calculate C_d for the condition when the nappe is not properly ventilated.

CONCLUSIONS

Does the magnitude of the flowrate affect the discharge coefficient C_d? Does C_d increase or decrease with increasing flowrate?

What is the pattern of the water as it passes over the weir?

Would you expect the length of the weir crest to affect the discharge coefficient C_d?

What is the effect of drowning the weir (increasing the downstream depth)?

Do your calculated values for C_v vary with flowrate?

EXPERIMENT D

Discharge beneath a Sluice Gate

OBJECTIVE

To determine the relationship between upstream head and flowrate for water flowing under a sluice gate (undershot weir); to calculate the discharge coefficient and to observe the flow patterns obtained.

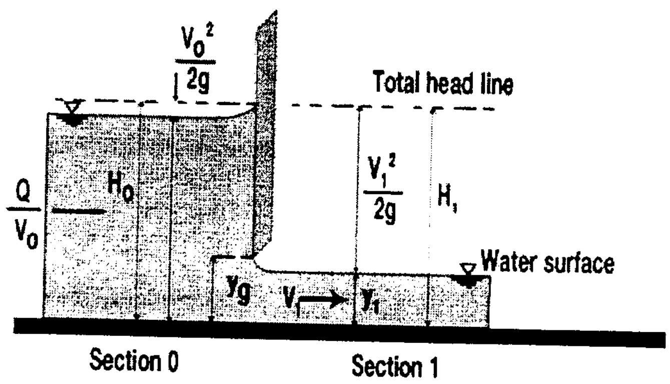
EQUIPMENT SET-UP

Multi-Purpose Teaching Flume, C4

Adjustable undershot weir

Hook and point gauge, 300mm scale – 2 required
Stopwatch if measuring flowrate using the volumetric tank (not supplied)

Note: If available, the Pitot tube and manometer, C4-61 (optional accessory) can be used to measure velocity of the water directly.



SUMMARY OF THEORY/BACKGROUND

For flow beneath a sharp edged undershot weir it can be shown that;

$$Q = C_d \, b \, y_g \sqrt{2 g y_o} \qquad \text{therefore:} \qquad C_d = \frac{Q}{b \, y_g \sqrt{2 g y_o}}$$

where:

Q	= Volume flowrate	($m^3.s^{-1}$)
	= Volume/time (using volumetric tank)	
C_d	= Discharge coefficient	(Dimensionless)
b	= Breadth of weir	(m)
y_g	= Height of weir opening above bed	(m)
y_0	= Upstream depth of flow	(m)
g	= Gravitational constant	($9.81 m \, s^{-2}$)

$$H_0 = y_0 \frac{V_0^{\,2}}{2g} = y_0 \frac{Q^2}{2g\,(y_0\, b)^2}$$

$$H_1 = y_1 \frac{V_1^{\,2}}{2g} = y_1 \frac{Q^2}{2g\,(y_1\, b)^2}$$

where:

H_0	= Total head upstream of weir	(m)
H_1	= Total head downstream of weir	(m)
y_1	= Downstream depth of flow	(m)
V_0	= Mean velocity upstream of weir	($m \, s^{-1}$)
V_1	= Mean velocity downstream of weir	($m \, s^{-1}$)

PROCEDURE

Ensure the flume is level, with no stop logs installed at the discharge end of the channel. Measure and record the actual breadth b (m) of the undershot weir.

Clamp the undershot weir assembly securely to the sides of the channel at a position approximately mid way along the flume with the sharp edge on the bottom of the weir facing upstream. For accurate results the gaps between the weir and the channel should be sealed on the upstream side using Plasticine.

Position two hook and point level gauges on the channel sides, one upstream of the weir and one downstream of the weir, each with the point fitted.

The datum for all measurements will be the bed of the flume. Carefully adjust the level gauges to coincide with the bed of the flume and record the datum readings.

Adjust the knob on top of the weir to position the sharp edge of the weir 0.020m above the bed of the flume.

Gradually open the flow control valve and admit water until y_o = 0.200m measured using the upstream level gauge. With y_o at this height, measure Q using the direct reading flowmeter or the volumetric tank with a stopwatch. Also measure y_1 using the downstream level gauge. Raise the weir in increments of 0.010m maintaining y_o at the height of 0.200m by varying the flow of water. At each level of the weir record the values of Q and y_1.

Repeat the procedure with a constant flow Q allowing y_o to vary. Record the values of y_0 and y_1.

RESULTS AND CALCULATIONS

Tabulate your readings and calculations as follows:

Breadth of weir, b = ...(m).

y_g	y_o	y_1	Q	C_d	H_0	H_1

Plot graphs of Q against y_g for constant y_0 and y_0 against y_g for constant Q to show the characteristics of flow beneath the weir.

Plot graphs of C_d against Q for constant y_0 and C_d against y_g for constant Q to show the changes in C_d of flow beneath the weir.

CONCLUSIONS

Comment on effects of y_o and Q on the discharge coefficient C_d for flow underneath the gate. Which factor has the greatest effect?

Comments on any discrepancies between actual and expected results.

Compare the values obtained for H_1 and H_0 and comment on any differences.