LAB #5
DISCHARGE OVER WEIRS

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Submitted by -
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ABSTRACT

This experiment was about discharge of flow of water over weirs which was conducted on ddth November, 2019 at Fluid Mechanics Laboratory. Discharge over Weirs experiment was conducted to investigate the characteristics of flow that showed by a rectangular and V-shaped Weir. The difference in flow rate of water that flows into both of the channel was observed. Besides that, the discharge coefficient of fluid flow was determined by calculation of this experiment values and compared with the accepted values. The experiment's procedures were followed to start the experiment. The depth of water was adjusted with different height and tested by recording the time taken to collect 15L of water. The time taken was used later to calculate the flow rate of the flow by each weir. Using the empirical equation, data obtained after the experiment was tabulated by calculating the discharge coefficient. Next, graphs were constructed to analyze the characteristics of the flow.

INTRODUCTION

The flow rate in pipes and ducts is controlled by various kinds of valves. Liquid flow in open channels, however, is not confined, and thus the flow rate is controlled by partially blocking the channel. This is done by either allowing the liquid to flow over the obstruction or under it. An obstruction that allows the liquid to flow over it is called a weir, and an obstruction with an adjustable opening at the bottom that allows the liquid to flow underneath it is called an underflow gate. Such devices can be used to control the flow rate through the channel as well as to measure it. A weir is a flow control device in which the water flows over the obstruction. In this experiment, the rectangular weirs and triangular weirs have been used. Rectangular weirs and triangular or v-notch weirs are often used in water supply, wastewater and sewage systems. They consist of a sharp edged plate with a rectangular, triangular or v-notch profile for the water flow. Broad-crested weirs can be observed in dam spillways where the broad edge is beneath the water surface across the entire stream. Flow measurement installations with broad-crested weirs will meet accuracy requirements only if they are calibrated.

OBJECTIVES

The main objective of this experiment was to obtain empirical equations for the flow of water over sharp-edged rectangular and v-shaped weirs and to compare the measured discharge coefficients with accepted values.

THEORY

Flow through a Rectangular Weir:

A rectangular weir in a thin squared edged weir plate installed in a weir channel as shown in Fig. 1.

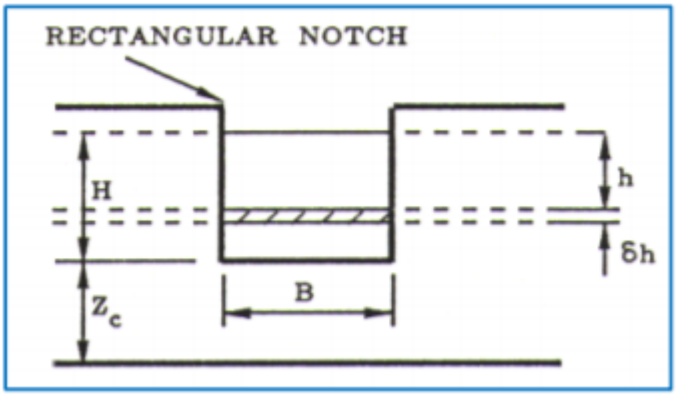

Figure 1: Rectangular Weir.

Consider the flow in an element of height δh at a depth h below the surface. Assuming that the flow is everywhere normal to the plane of the weir and that the free surface remains horizontal up to the plane of the weir, then using Bernoulli's equation with no head loss and 1-D flow, we get the velocity at point 2 as shown in Fig. 2.

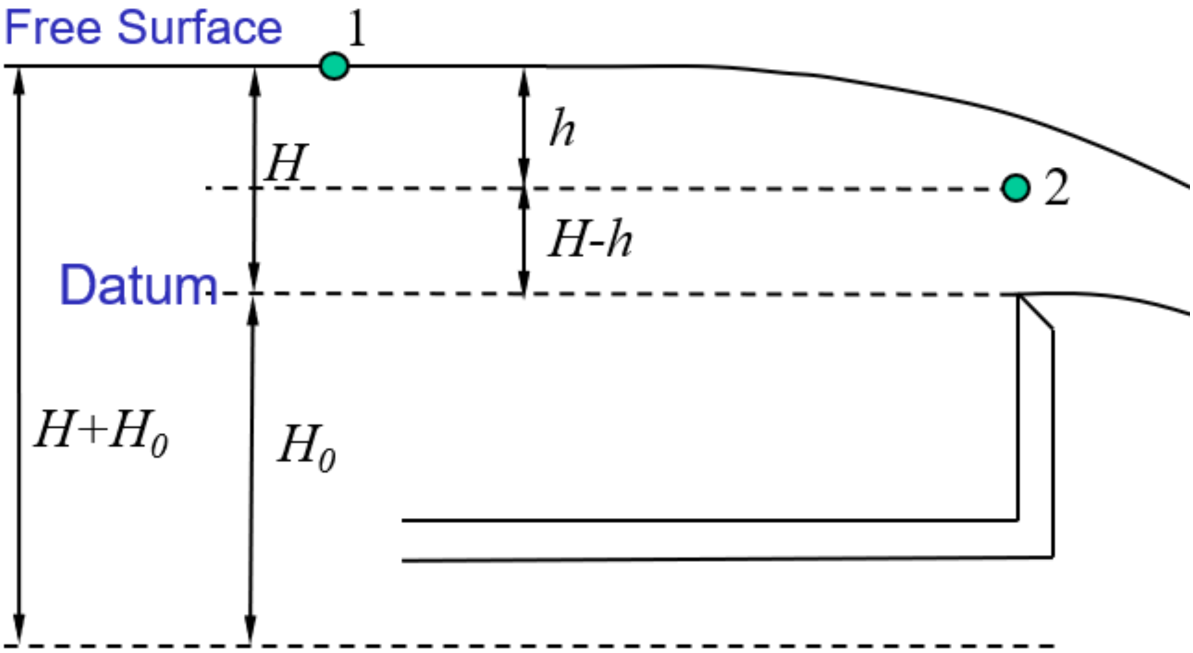

Figure 2: Two points on the weir for Bernoulli's equation application.

$$p_1 + \frac{1}{2}\rho V_1^2 + \rho g z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \rho g z_2$$

$$p_1 = p_{atm} \; ; \; p_2 = p_{atm}$$

$$V_1 = 0 \; ; \; z_1 - z_2 = h$$

$$V_2 = \sqrt{2gh}$$

Where, V_2 is velocity through the element.

Theoretical discharge through element $\delta Q = VdA = \sqrt{2gh}B\delta h$
Where, B is the width of the weir.
Integrating to obtain the total discharge between h = 0 and h = H

$$Q_{theo} = B.\sqrt{2g}.\int_0^H h^{1/2}.dh$$
$$Q_{theo} = \frac{2}{3}.B.\sqrt{2g}.H^{3/2}$$

In practice the flow through the notch will not be parallel and therefore will not be normal to the plane of the weir. The free surface is not horizontal and viscosity and surface tension will have an effect. There will be a considerable change in the shape of the nappe as it passes through the notch with curvature of the streamlines in both vertical and horizontal planes as indicated in Fig. 3, in particular the width of the nappe is reduced by the contractions at each end.

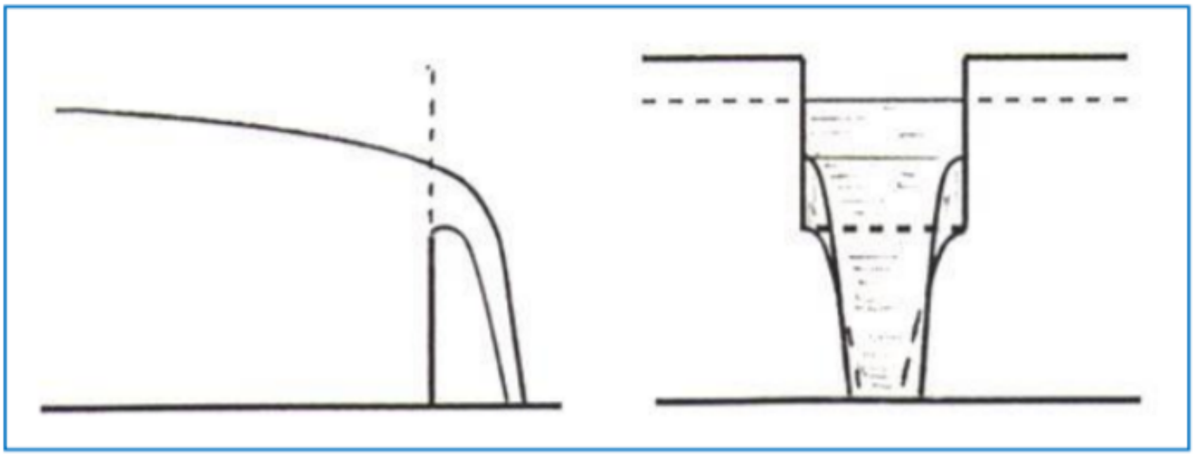

Figure 3: Shape of a nappe.

The discharge from a rectangular notch will be considerably less, approximately 60% of the theoretical analysis due to these curvature effects. A coefficient of discharge C_d is therefore introduced so that:

$$Q_{act.} = Q_{theo.}$$
$$Q_{act.} = C_d.\frac{2}{3}.B.\sqrt{2g}H^{3/2}$$
$$\ln(Q_{act.}) = \ln(C_d.\frac{2}{3}.B.\sqrt{2g}) + \frac{3}{2}\ln(H)$$
$$y = \text{intercept} + (3/2).x$$

$$C_d = \frac{e^{intercept}}{\frac{2}{3}.B.\sqrt{2g}}$$

Flow through a Triangular Weir (V-shaped Weir):

A sharp edged triangular notch with an included angle of θ is shown in Fig. 4.

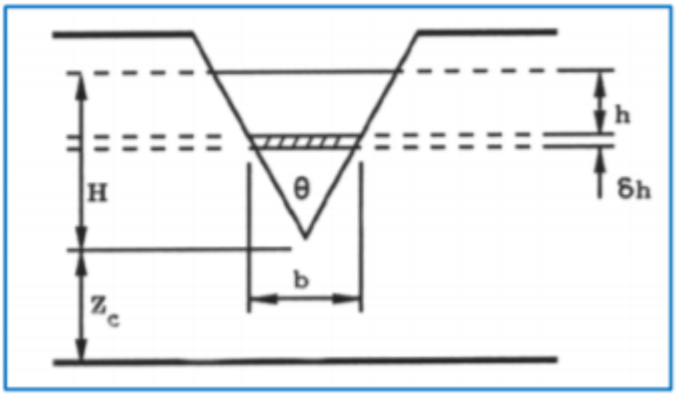

Figure 4: Triangular Weir.

Again consider an element of height δh at a depth h
Breadth of the element, b = 2.(H - h).Tan(θ/2)
Hence, Area of element, A = 2.(H - h).Tan(θ/2).δh
Velocity through element, $V_2 = \sqrt{2gh}$
Theoretical discharge through element $\delta Q = VdA = \sqrt{2gh}.2.(H - h).Tan(\theta/2).\delta h$
Integrating to obtain the total discharge between h = 0 and h = H

$$Q_{theo} = 2.\tan(\theta/2).\sqrt{2g}.\int_0^H [Hh^{1/2} - h^{3/2}].dh$$
$$Q_{theo} = \frac{8}{15}.\tan(\theta/2).\sqrt{2g}.H^{5/2}$$

Again, a coefficient of discharge C_d has to be introduced.

$$Q_{act.} = C_d.\frac{8}{15}.\tan(\theta/2).\sqrt{2g}.H^{5/2}$$

The triangular notch has advantages over the rectangular notch since the shape of the nappe does not change with head so that the coefficient of discharge does not vary so much. A triangular notch can also accommodate a wide range of flow rates.

$$\ln (Q_{act.}) = \ln (C_d.\frac{8}{15}.\tan(\theta/2).\sqrt{2g}) + (5/2).\ln (H)$$
$$y = \text{intercept} + (5/2).x$$

$$C_d = \frac{e^{intercept}}{\frac{8}{15}.tan(\theta/2).\sqrt{2g}}$$

PROCEDURE

1. Start the pump and slowly open the bench regulating valve until the water level reaches the crest of the weir and measure the water level to determine the datum level.

2. Adjust the bench regulating valve to give the first required head level of approximately 4 - 8 mm. Measure the flow rate using the volumetric tank or the rotameter.
3. Increase the flow by opening the bench regulating valve to set up heads above the datum level in steps of approximately 8 mm until the regulating valve is fully open. At each condition measure the flow rate.
4. Close the regulating valve, stop the pump and then replace the weir with the next weir to be tested. Repeat the test procedure.

RESULTS AND DISCUSSION

The measured and collected Data for rectangular and V-shaped Weir are tabulated in Table 1 and 2.

Table 1: Rectangular Weir Data.

H_0	Volume	Time	$H + H_0$	H	H	Q
(mm)	(litres)	(sec)	(mm)	(mm)	(m)	(m^3/s)
80	15	14	136	56	0.056	0.0010714285714
80	15	16.6	128	48	0.048	0.0009036144578
80	15	22	120	40	0.04	0.0006818181818
80	15	25	112	32	0.032	0.0006000000000
80	15	33	104	24	0.024	0.0004545454545
80	15	63	96	16	0.016	0.0002380952381
80	5	56	88	8	0.008	0.0000892857143
80	5	83	80	0	0	0.0000602409639

Table 2: V-shaped Weir Data.

H_0	Volume	Time	$H + H_0$	H	H	Q
(mm)	(litres)	(sec)	(mm)	(mm)	(m)	(m^3/s)
96	15	14.16	160	64	0.064	0.00105932
96	15	18.5	152	56	0.056	0.00081081
96	15	23	144	48	0.048	0.00065217
96	15	25	136	40	0.04	0.00060000
96	15	32	128	32	0.032	0.00046875
96	15	41	120	24	0.024	0.00036585
96	15	60	112	16	0.016	0.00025000
96	5	68	104	8	0.008	0.00007353
96	5	75	96	0	0	0.00006667

From the data collected, log values of flow rate and height are calculated for both the weirs and graph is plotted between log Q and logH and are shown in Fig. 5 and 6.

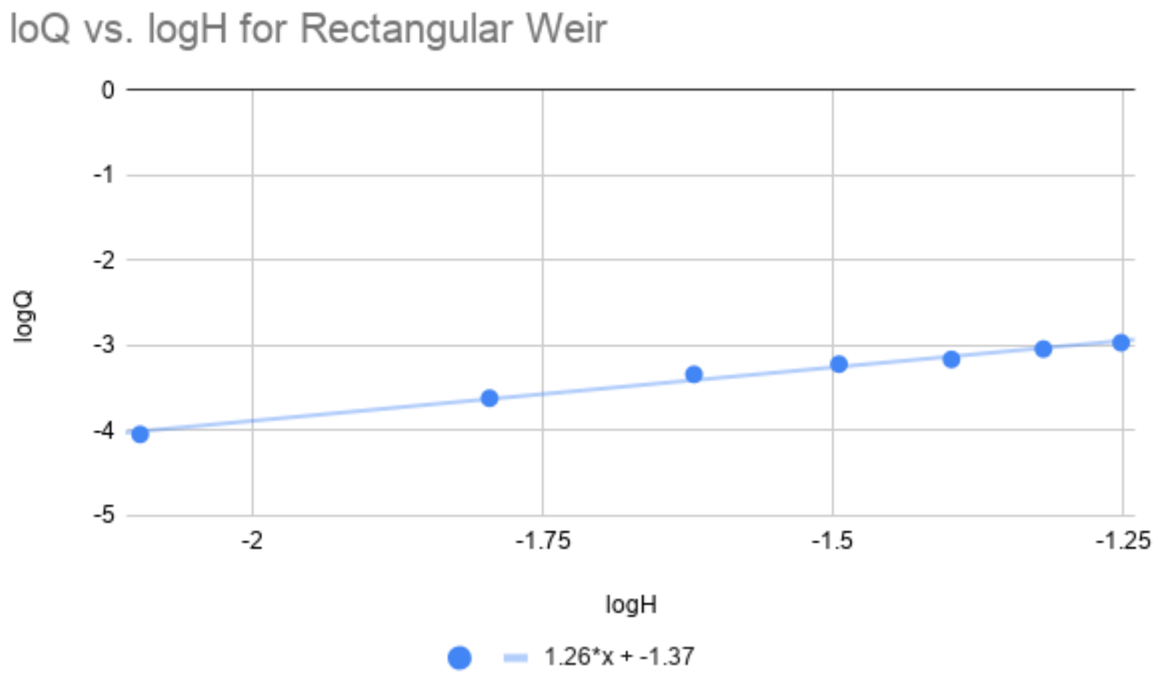

Figure 5: logQ vs. logH for Rectangular Weir.

The graph shows a straight line in the form of y = mx + c. From this equation, we can calculate the discharge coefficient from the intercept "c". For doing this, we take the slope of the equation as the theoretical value (i.e. m = 1.5).

We know that, intercept = -1.37. So,

$$\text{Intercept} = \log(C_d.\tfrac{2}{3}.B.\sqrt{2g})$$

$$-1.37 = \log(C_d.\tfrac{2}{3}.B.\sqrt{2g})$$

$$10^{-1.37} = C_d.\tfrac{2}{3}.B.\sqrt{2g}$$

$$C_d = \frac{10^{-1.37}}{\frac{2}{3}\,x\,0.03\,x\,\sqrt{2\,x\,9.81}} = 0.4815$$

From the literature, we know that discharge coefficient of Rectangular Weir is 0.68 and from the vendor 0.59. But the from the experimental calculations, we got 0.4815. This is because we took the slope of the graph as theoretical value and not the obtained value from the graph.

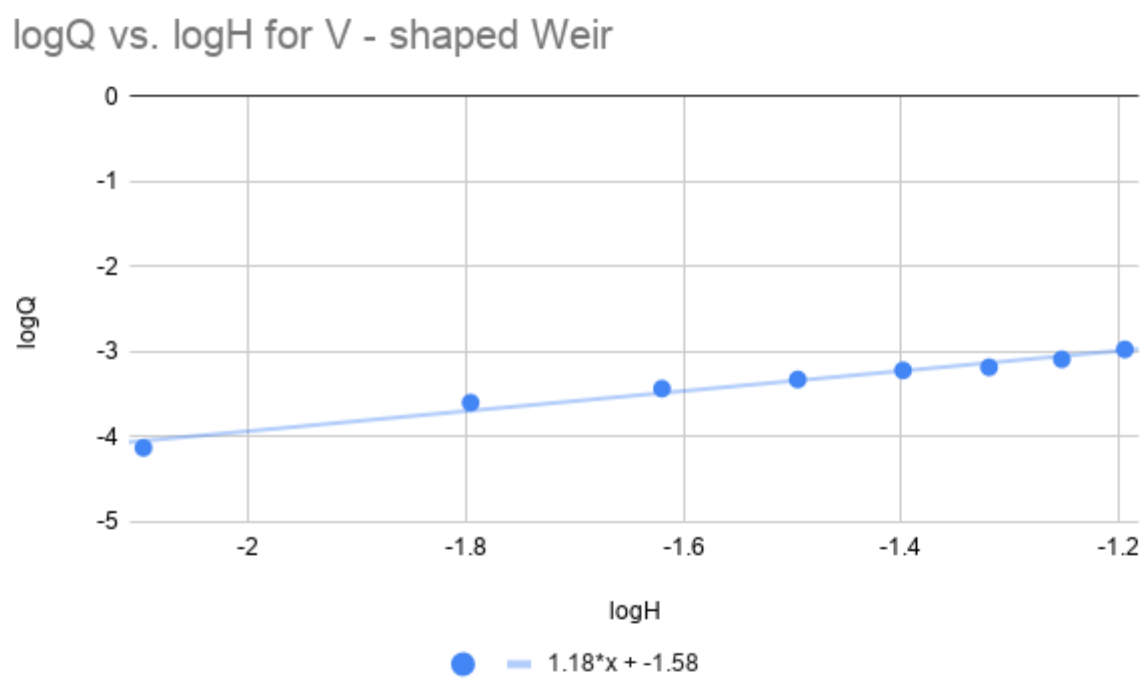

Figure 6: logQ vs. logH for V-shaped Weir.

We find the discharge coefficient for this weir same as the above. So, intercept = -0.58 (since, forcing the slope to 2.5, we get the intercept to be -0.58).

$$\text{Intercept} = \log\left(C_d.\frac{8}{15}.\tan(\theta/2).\sqrt{2g}\right)$$

$$-0.58 = \log\left(C_d.\frac{8}{15}.\tan(\theta/2).\sqrt{2g}\right)$$

$$10^{-0.58} = C_d.\frac{8}{15}.\tan(\theta/2).\sqrt{2g}$$

$$C_d = \frac{10^{-0.58}}{\frac{8}{15}.\tan(15.1)\ x\ \sqrt{2\ x\ 9.81}} = 0.4126$$

From the literature, we know that discharge coefficient of V-shaped Weir is 0.64 and from the vendor 0.62. But the from the experimental calculations, we got 0.4126. This is because we took the slope of the graph as theoretical value and not the obtained value from the graph.

From the 3 discharge coefficients, we can state that the most credible discharge coefficient is from the vendor. This can be explained because the vendor tests the weir without any ideal conditions like in the literature and gives us the safety design discharge coefficient. But from the experimental value, we have many errors that has not taken into consideration and hence not credible.

CONCLUSION

The smooth flow to and over the weir is essential to the determination of accurate rates of flow since the distribution of velocities on the approach flow has a definite influence on the discharge over the weir. The empirical equation and discharge coefficients were found for the rectangular and V-shaped weir and compared with the literature and vendor values. The limitations of the theory is that it has to be level so the only force on the water is gravity, there has to be a constant flow, and constant pressure.The theory behind this experiment makes an assumption that there is a minimum height of water above the notch and any heights below this start to deviate from theory at an increasing rate.The relationship between the head of the weir and the discharge of the water over the weir is directly proportional. The lower flow rates produce lower heights above the notch creating larger changes from the theoretical equations.

REFERENCES

[1]https://www.academia.edu/18747051/CHE241_-_Lab_Report_Solteq_Flow_Over_Weirs_FM26_2015_
[2] http://site.iugaza.edu.ps/mymousa/files/Experiment-6-hydraulics-lab-.pdf