DEPARTMENT OF CIVIL ENGINEERING

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

CE 362 Open channel flow sessional

Experiment No. 3

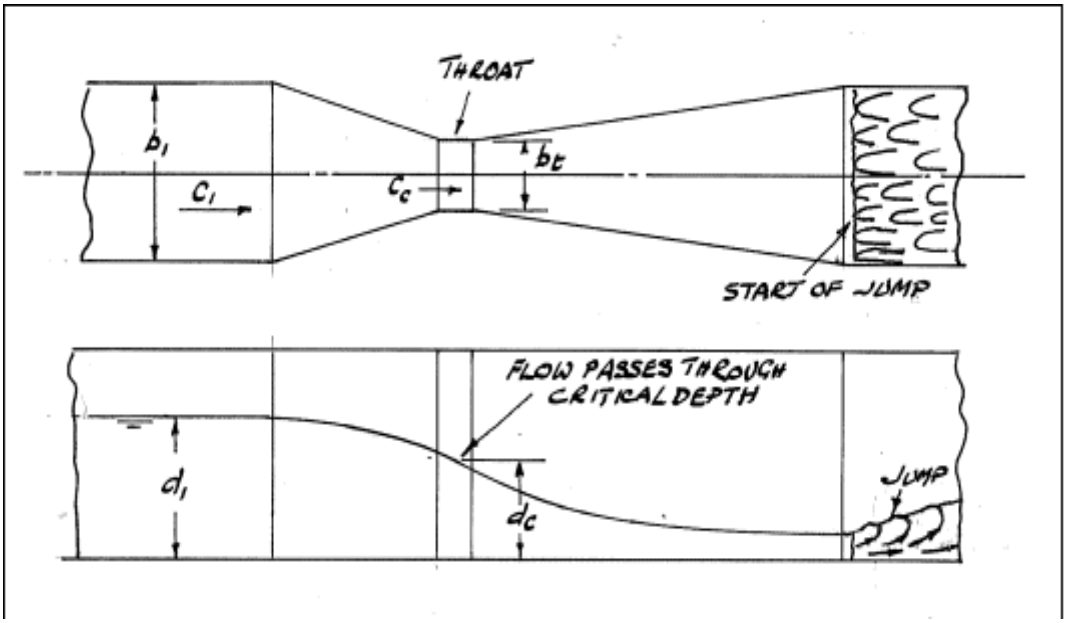
FLOW THROUGH A VENTURI FLUME

3.1 General

A **Venturi flume** is a critical-flow open flume with a constricted flow which causes a drop in the hydraulic grade line, creating a critical depth.

It is used in flow measurement of very large flow rates, usually given in millions of cubic units. A Venturi meter would normally measure in millimeters, whereas a Venturi flume measures in meters.

For measurement of discharge with Venturi flumes two measurements, one upstream and one at the throat (narrowest cross-section), are required, if the flow passes in a subcritical state through the flume. If the flumes are designed so as to pass the flow from sub critical to supercritical state while passing through the flume, a single measurement at the throat (which in this case becomes a critical section) is sufficient for computation of discharge. To ensure the occurrence of critical depth at the throat, the flumes are usually designed in such way as to form a hydraulic jump on the downstream side of the structure. These flumes are called 'standing wave flumes'



Basis of design of the Venturi flume

Although weirs are an effective method of artificially creating a critical section at which the flow rate can be determined, a weir installation has at least two disadvantages. First, the use of weirs results in relatively high head loss. Second, most weirs create dead water zone upstream of the installation which can be served as a settling basin for sediment and other

debris present in the flow. Both of these disadvantages can be overcome with an open flume having a contraction in width which is sufficient to cause the flow to pass through a critical depth. Venturi flume is an open flume used widely in irrigation canal for measuring discharge and also as an outlet of canal to supply water in the field or distributor canal. But Venturi flumes have a disadvantage that there is relatively small head difference between upstream section and critical section, especially in low Froude number. This experiment deals with measurement of discharge using a Venturi flume and also calibration of the flume.

Comparison with weirs

Venturi flumes have two advantages over weirs where the critical depth is created by a vertical constriction. First, the hydraulic head loss is smaller in flumes than in weirs. Second, there is no dead zone in flumes where sediment and debris can accumulate; such a dead zone exists upstream of the weirs.

3.2 Practical applications

1. It is used in flow measurement of very large flow rates, usually given in millions of cubic units.

	
University of Arizona Valley farm submerged flume site	**Genesis manufactures flumes**

3.3 Theory

Considering critical flow occurs at throat section of the flume, the theoretical discharge at free flow is given by,

$$Q_{tf} = AV = A_c V_c$$

Where A_c and V_c are the area and velocity at critical section of the flume.

For critical state of flow,

$$F_r = 1$$

$$\text{or}, \quad \frac{V_c^2}{gD_c} = 1$$

$$\text{or}, \quad v_c = \sqrt{(gD_c)}$$

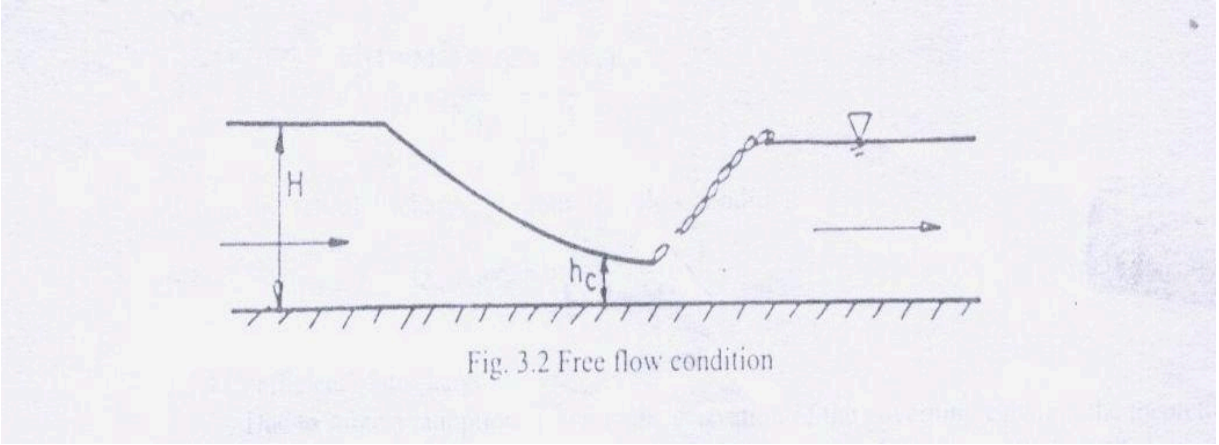


Fig. 3.2 Free flow condition

Now, for a rectangular flume, $A_c = by_c$ and $D_c = y_c$, where b is the width of the Venturi flume at throat section. Hence theoretical discharge is given by,

$$Q_{tf} = A_c V_c = by_c\sqrt{gy_c} \qquad \text{.....} \qquad (3.1)$$

Now for a rectangular channel at critical section there exists a relationship between total head and total depth of flow as $H = \frac{3}{2}y_c$. Hence putting $y_c = \frac{2}{3}H$, Eq. (3.1) stands as,

$$Q_{tf} = \left(\frac{2}{3}\right)^{1.5\sqrt{g}}\, b\, H^{1.5} \qquad \text{.....} \qquad (3.2)$$

Where H = Head measured sufficiently upstream of the flume.

3.3.1 Theoretical Discharge in Submerged Flow Condition:

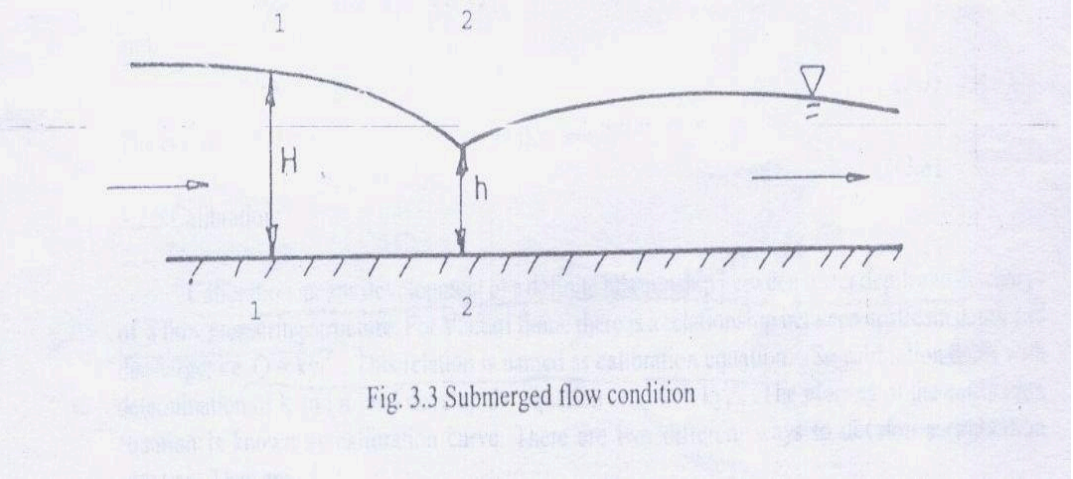


Fig. 3.3 Submerged flow condition

During submerged flow condition there exists no critical section. Considering Fig 3.3, applying energy equation between section 1 and 2,

$$y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g}$$

or, $v_2^2 - v_1^2 = 2g\,(y_1 - y_2)$

or, $v_2^2\left(1 - \frac{v_1^2}{v_2^2}\right) = 2g\,(y_1 - y_2)$

Now, if A and a are the cross sectional area at section 1 and 2 respectively then, using continuity equation,

$$Av_1 = av_2$$

$$\frac{v_1}{v_2} = \frac{a}{A} = M \text{ (Let)}$$

So,

$$v_2^2\,(1 - M^2) = 2g\,(y_1 - y_2)$$

$$v_2 = \sqrt{\frac{(2g\,(y_1 - y_2)}{1 - M^2}}$$

Hence theoretical discharge at submerged flow condition

$$Q_{ts} = av_2 = a\sqrt{\frac{(2g\,(y_1 - y_2)}{1 - M^2}} \qquad \text{.....(3.3)}$$

3.3.2 Coefficient of discharge:

Due to some assumptions taken in the derivation of governing equation the theoretical discharge and the actual discharge always varies from each other. So coefficient of discharge introduced. If Q_a is the actual discharge, then the coefficient of discharge at free flow condition, C_{df} is given by,

$$C_{df}=\frac{Q_a}{Qtf} \quad \text{.....(3.4)}$$

Normally, in a field installation it is not possible to measure the energy head H directly and therefore the discharge is relate to the upstream depth of flow, y_1 in the following way,

$$Q_a = C_v C_{df} \left(\frac{2}{3}\right)^{1.5} \sqrt{g}\, b\, y_1^{1.5} \quad \text{..... (3.5)}$$

Where C_v is the correction coefficient for neglecting the velocity head in the approach channel. Generally the effects of C_v is considered in C_d and finally the governing equation stands as,

$$Q_a = C_{df} \left(\frac{2}{3}\right)^{1.5\sqrt{g}}\, b\, y_1^{1.5} \quad \text{..... (3.6)}$$

And

$$Q_{tf} = \left(\frac{2}{3}\right)^{1.5\sqrt{g}}\, b\, y_1^{1.5} \quad \text{..... (3.7)}$$

The coefficient of discharge at submerged flow condition, C_{ds} is given by,

$$C_{ds} = \frac{Q_a}{Qts} \quad \text{.....(3.8)}$$

3.3.3 Calibration:

Calibration means development of a definite relationship between water depth anddischarge of a flow measuring structure. For Venturi flume there is a relationship between upstream depth and discharge i.e. $Q = ky_1^n$. This relation is named as calibration equation. So calibration deals with determination of k and n and develop the equation is known as calibration equation. There are two different ways to develop a calibration equation. They are:

1. Plotting best fit line by eye estimation
2. Developing best fit line by regression

By eye estimation:

As, log Q = n log y_1 + log k so, if Q and y_1 are plotted in a log-log paper the graph will represent a straight line. So, different set of Q_a and y_1 are plotted in log-log paper keeping y_1 in x axis and Q in y axis. The best fit line is drawn by eye estimation. The slope of the line gives the value of n. Then for any value of y corresponding Q_a is found from the best fit line. Using these value of h and Q and n the value of K can be found from the equation $Q = ky_1^n$.

By regression:

$Q = ky_1^n$

$\Rightarrow \log Q = \log k + n \log y_1$

Let, $\log Q = y$, $\log y_1 = X$, $\log k = K$

So, $Y = K + nX$

Then,

$$n = \frac{N\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{N\left(\sum X^2\right) - \left(\sum X\right)^2}$$ Where, N= Number of data

And $$K = \frac{\left(\sum Y\right) - n\left(\sum X\right)}{N}$$

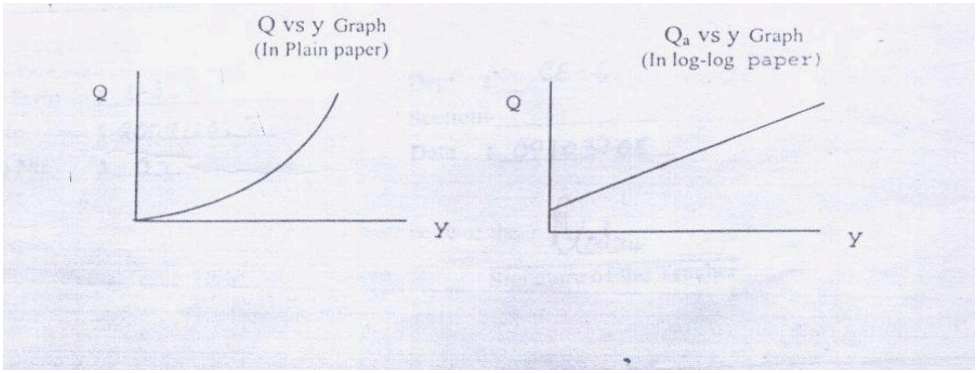
So, K= anti log K

The correlation co-efficient is given by,

$$r = \frac{N\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\left(\sqrt{N\left(\sum X^2\right) - \left(\sum X\right)^2}\right)\left(\sqrt{N\left(\sum Y^2\right) - \left(\sum Y\right)^2}\right)}$$

For a perfect correlation, r=1.0. If r is between 0.6 and 1.0 it is generally taken as a good correlation.

Q vs. y graph: As, generally, $Q=ky^n$ so, in plain paper the graph will be parabola. But in log-log paper it will be an straight line as log Q = n log y + log k which is a equation of straight line (y = mx + c)



3.4 Objectives

1. To determine the theoretical discharge of the flume at free flow and Submerged flow condition.

2. To measurement the actual discharge and hence to find out the coefficient of Discharge at free flow and submerged flow.

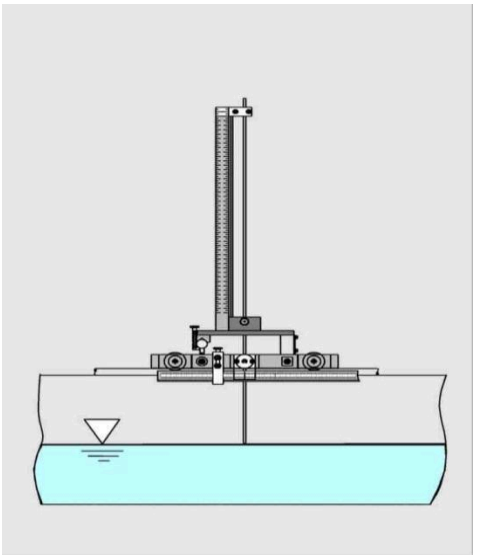
3. To calibrate the flume.

3.6 Apparatus

Flow channel, Broad crested weir, instrument carriage etc.



Broad crested weir



instrument carriage



Flow channel

3.5 Procedure

Determination of theoretical discharge and coefficient of discharge in free flow condition:

1. Measure the depth of flow upstream of the flume and determine the theoretical discharge using equation 3.7

2. Take the reading of actual discharge and hence found find the coefficient of discharge using Eq. 3.4

Determination of theoretical discharge and coefficient of discharge is submerged flow condition:

1. Measure the depth of flow at section 1 and section 2 and determine the theoretical discharge equation 3.3

2. Take the reading of actual discharge and hence find the coefficient of discharge using equation 3.8

Calibration of the flume (**for free flow condition only**):

By eye estimation:

1. Plot actual discharge against different upstream depth of flow over the crest in a log log paper and find the value of n and k as discussed in article 3.2.5
2. develop the relationship $Q = ky_1^n$

By regression:

1. From a table having columns Q, y_1, X, Y, XY, X^2, Y^2 as discussed in article 3.2.5 (Detailed given in calculation portion) and the value of n, k and r.
2. Compare the equation formed by eye estimation method.

3.7 DATA SHEET

FLOW THROUGH A VENTURI FLUME

Channel width, B = 0.6m /0.31m Throat width, b =0.291m/0.148m

Gp	Free Flow Condition				Submerged Flow Condition					
	, Q_a (m^3/s)	y_1 (m)	$Q_{tf} = (\frac{2}{3})^{1.5\sqrt{g}}$ b $H^{1.5}m^3/s$)	C_{df}	Actual discharge (m^3/s)	y_1 (m	y_2 (m)	M	Q_{ts} ($Q_{ts} = av_2 = a\sqrt{\frac{(2g(y_1-y_2)}{1-M^2}}$ m^3/s)	C_{ds}
1										
2										
3										

4										
5										

Level / Term : **Dept. :**
Reg No. : **Section:**
Group No. : **Date :**

Signature of the Teacher

3.8Calculation

Calibration of flume:

1. By eye estimation:

Actual discharge, $Q_a(m^3/s)$	Depth of water at upstream,$y_1(m)$

Calculation from graph:

2. By regression:

y_1	Q	X=log y_1	Y= logQ	XY	X^2	Y^2
Summation		$\sum X =$	$\sum Y =$	$\sum XY =$	$\sum X^2 =$	$\sum Y^2 =$

$$n = \frac{N\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{N\left(\sum X^2\right) - \left(\sum X\right)^2} =$$

$$K = \frac{\left(\sum Y\right) - n\left(\sum X\right)}{N} =$$

K= Antilog K=

$$r = \frac{N\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\left(\sqrt{N\left(\sum X^2\right) - \left(\sum X\right)^2}\right)\left(\sqrt{N\left(\sum Y^2\right) - \left(\sum Y\right)^2}\right)} =$$

Equation,

$Q = ky_1^n$

3.9 Assignment

1. What are the advantages, disadvantages and uses of Venturi flume?

2. What is the difference between free flow and submerged flow? How can you create submerged flow in laboratory flume?

3.10 Discussion