Determination of state of flow and critical depth in open channel

1.1 General:

Open channel flow is generally affected by different fluid properties such as viscosity, density, surface tension etc and also the gravity. These effects results different state of flow in open channel. This experiment mainly deals with determination of the state of flow in an open channel at a particular section. The state of flow is very important, as the flow behaviour is depends on it. In order to construct different structures in rivers and canals and to predict the river response the state of flow must be known. The experiment also deals with determination of critical depth, which is very useful in determining different flow phenomena.

$F_v = \mu\left(\frac{du}{dy}\right)A = \mu \frac{V}{L}\cdot L^2 = \mu VL$

$F_I = ma = \rho L^3 \cdot \frac{L}{T^2} = \rho L^4 T^{-2} = \rho \frac{L^2}{T^2} L^2 = \rho V^2 L^2$

1.2 Theory:

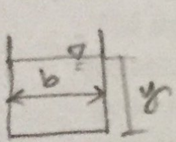
1.2.1 State of flow:

State of flow is an open channel is based on the combined effect of Viscosity and Gravity. Depending on the effect of viscosity relative to the inertia, the flow may be laminar turbulent or transition. The effect of viscosity relative to the inertia is expressed by the Renyolds number given by,

$F_I = \rho V^2 L^2$

$F_v = \mu V L$

$Re = \frac{\text{Inertia}}{\text{Viscosity}} = \frac{F_I}{F_v}$



$$R_e = \frac{VR}{\nu} \tag{1.1}$$

$\therefore Re = \frac{\rho V^2 L^2}{\mu V L} = \frac{VL}{\mu/\rho}$

A =

$\therefore Re = \frac{VL}{\nu}$

where, V = Mean velocity

R = Hydraulic radius =A/P
A=Wetted area $A = by$
P=Wetted perimeter $P = b + 2y$
ν = Kinemetic viscosity of water.

Kinematic viscosity vary with temperature. The value of ν at different temperature is given in Table 1.1

When, $R_e < 500$	the flow is laminar
$500 \le R_e$ 12, 500	the flow is transitional
$R_e > 12500$	the flow is turbulent.

Most open channel flows including those in rivers and canals are turbulent. The Reynolds number of most open channel flows is high, of the order of 10^6, indicating that the viscous forces are weak relative to the inertia forces and do not play a significant role in determining the flow behaviour.

Depending on the effect of gravity the flow is classified as supercritical, critical and subcritical flow. The effect of gravity relative to the internal force is expressed by the Froude number, defined as

$$F_r = \frac{V}{\sqrt{gD}} \qquad (1.2)$$

Gravity force,
$F_G = mg = \rho L^3 g$

$\therefore F_r = \frac{\text{Inertia}}{\text{Gravity}} = \frac{\rho V^2 L^2}{\rho L^3 g} = \frac{V^2}{gL}$

$\therefore F_r = \frac{V}{\sqrt{gL}}$

Where,

V = Mean velocity
D = Hydraulic mean depth=A/T
A=Wetted area
T=Top width
g = Gravitational acceleration

$A = by$, $T = b$

$\therefore \frac{A}{T} = \frac{by}{b} = y$

$\therefore D = y$

When, Fr>1 the flow is supercritical
Fr=1 the flow is critical
Fr<1 the flow is subcritical

Generally the flow in most rivers and canals is subcritical. Since the state of open channel flow is primarily governed by the gravity forces relative to the inertia force, the Froude number is the most important parameter to indicate the state of flow.

Depending on Froude number and Reynolds number, the following four states of flow are possible.

i)Subcritical Laminar	Fr<1, Re<500
ii)Supercritical laminar	Fr>1, Re<500
iii)Subcritical turbulent	Fr<1, Re>12500
iv)Supercritical turbulent	Fr>1, Re> 12500

The first two states of flow, subcritical laminar and super critical laminar are not commonly encountered in applied open channel hydraulics. Since the flow is generally turbulent is open channel, the last two states of flow are considered is engineering problem.

Table: 1.1 Physical properties of water.

Temperature, ^{0}C	Kinematic viscosity vx10^{-6} m^2/s
	1.781
	1.518
10	1.307
15	1.139
20	1.002
25	0.890
30	0.798
40	0.653
50	0.547
60	0.466
70	0.404
80	0.354
90	0.315
100	0.282

1.2.2 Critical depth:

Critical depth is the depth at which the velocity is such that the Froud number is equal to unity for a given discharge and channel section.

So, putting F_r=1 in Eq.(1.2) using $\frac{V^2}{2g}=\frac{D}{2}$ and simplifying, one get, for rectangular section

$$y_c = \sqrt[3]{\frac{Q^2}{gB^2}} \qquad (1.3)$$

$$\frac{V}{\sqrt{gD}} = 1 \Rightarrow \frac{V^2}{gD} = 1 \Rightarrow \frac{Q^2}{A^2 g} = D \Rightarrow \frac{Q^2}{A^2 g} = \frac{A}{T} \Rightarrow Q^2/g = A^3/T \Rightarrow Q^2/g = \frac{b^3 y^3}{b} \Rightarrow Q^2/g = y_c^3 b^2 \quad \therefore y_c = \sqrt[3]{\frac{Q^2}{gb^2}}$$

where,

y_c= Critical depth
Q=Discharge
B =Width of the channel

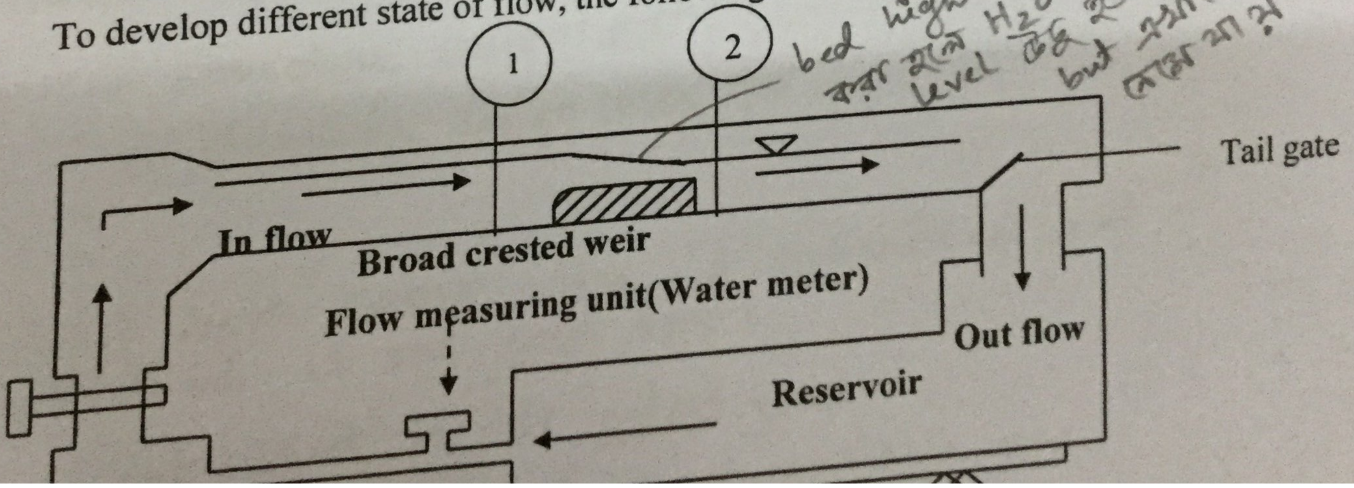
In critical depth the flow is critical. When the depth is greater the than the critical depth the flow is subcritical and when the depth is less than the critical depth the flow is supercritical.

1.3 Objectives of the experiment:

1) To measure water depth at both u/s and d/s of a weir.
2) To determine the R_e and F_r
3) To determine and observe the state of flow.
4) To determine critical depth
5) To observe the subcritical and supercritical flow.

1.4 Experimental Setup:

To develop different state of flow, the following laboratory setup is used.



1.5 Procedure:

i) Measure the depth of flow at section 1 and section 2 by point gage.
ii) Take the reading of discharge from water meter.
iii) Calculate velocity at both section.
iv) Calculate R_e and F_r for both section using Eq.(1.1) and (1.2) and determine the state of flow.
v) Calculate critical depth y_c using Eq.(1.3)

1.6 Assignment:

1. Why the state of flow and critical depth of a river need to be determined?
2. How can you determine that the flow in a river is subcritical, critical or supercritical without taking any measurement?
3. Reynolds no and Froude no, which one is more significant in determining flow behavior of a river? Why? ⇒ F_r is more significant cz it is gravity force and for open channel flow, gravity force is significant.

1.7 References:

i) Chapter –1 (Open channel flow and its classification), Chapter –4 (Critical Flow: Its Computation and Applications), Open Channel Hydraulics-By, Ven Te Chow.

ii) Chapter –1(Concept of fluid flow), Open Channel Hydraulics-By, Richard H. French

• Purpose of determining critical depth:
critical depth measure করা হয় —

1. structure কোথায় হবে
2. structure design কেমন হবে

• critical depth যেকোন time-এ subcritical and supercritical-এ চলে যেতে পারে।

  • subcritical is the safest zone
  • supercritical is the most unstable zone

Experiment No. 2

Flow over Broad Crested weir

• Agvantage { 1. easily constructed & set up
2. Low cost device

2.1 General:

A broad crested weir is an overflow structure with a truly level and horizontal crest. It is widely used in irrigation canals for the purpose of flow measurement as it is rugged and can stand up well under field condition. But practically some problem arises with the weir as there exists a dead water zone at the upstream of the weir and the head loss is more comparable to other device. This experiment deals with measurement of discharge using the broad crested weir and also calibration of the weir.

• Disadvantage { সেখানে velocity কমে যায় i.e. flow ধীর
তাই সেখানে sedimentation হয়ে
DEAD WATER ZONE create হয়

2.2 Theory:

2.2.1 Description of the weir:

The broad crested has a definite crest length in the direction of flow. In order to maintain a hydrostatic pressure distribution above the weir crest i.e. to maintain the stream lines straight and parallel, the length of the weir is designed such that $0.07 \le H_1/L \le 0.05$ where H_1 is the head above the crest and L is the length of the weir. The upstream corner of the weir is rounded in such a manner that flow separation does not occur

• Assumptions—
1. $0.07 \le H/L \le 0.5$
2. upstream corner is rounded so that no flow separation will occur

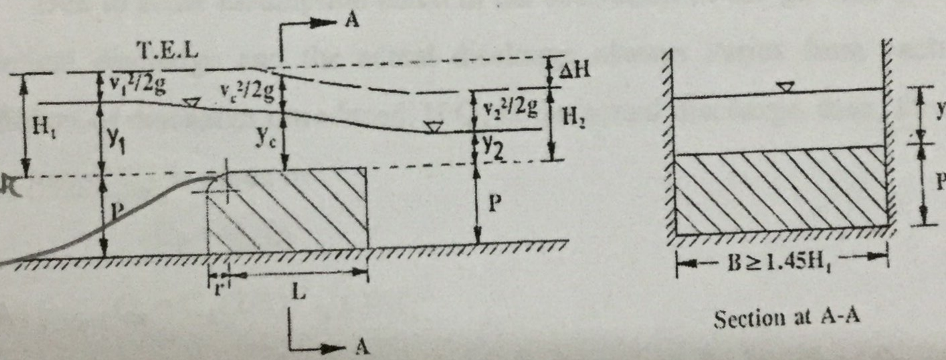


Fig. 2.1 Flow over a broad-crested weir

2.2.2 Theoretical discharge:

Consider the broad-crested weir shown in Fig. If there is no significant energy loss, according to Bernoulli's equation,

• considering head loss is negligible -

$$H_1 = y_1 + \frac{v_1^2}{2g} = H = y + \frac{v^2}{2g}$$

$$\Rightarrow H_1 = y + \frac{v^2}{2g}$$

$$\Rightarrow v = \sqrt{2g(H_1 - y)}$$

So, Theoretical discharge,

$$Q_t = Av = A\sqrt{2g(H_1 - y)}$$

Provided the critical flow occurs at control section ($y = y_c$), then

$$Q_t = By_c\sqrt{2g(H_1 - y_c)} \tag{2.1}$$

where B is the width of the weir. Now, for a rectangular channel at critical section there exists a relationship between total head and depth of flow as $H=3/2\ y_c$. Hence putting $y_c = 2/3\ H_1$, Eq.(2.1) stands as,

$$Q_t = (2/3)^{1.5}\sqrt{g}\,BH_1^{1.5} \tag{2.2}$$

2.2.3 Coefficient of discharge:

Due to some assumption taken in the derivation of the 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, C_d, is given by

$$C_d = Q_a/Q_t \tag{2.3}$$

Then,
$$Q_a = C_d(2/3)^{1.5}\sqrt{g}\,BH_1^{1.5} \tag{2.4}$$

Coefficient of discharge for the broad weir is depend on the length of the weir and the whether the upstream corner of the weir is rounded or not. Normally, in a field installation it is not possible to measure the energy head H_1 directly and therefore the discharge is relate to the upstream depth of flow over the crest, y_1 in the following way,

$$Q_a = C_v C_d(2/3)^{1.5}\sqrt{g}\,By_1^{1.5} \tag{2.5}$$

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

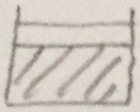
y_1 measure করব ⇒ Q_t

Q_a → flow meter থেকে নিব

then

$C_d = \frac{Q_a}{Q_t}$ ⇒ C_d = determined.

and,
$$\begin{cases} Q_a = C_d(2/3)^{1.5}\sqrt{g}\,By_1^{1.5} & (2.6) \\ Q_t = (2/3)^{1.5}\sqrt{g}\,By_1^{1.5} & (2.7) \end{cases}$$



Suppose, 2m → depth of flow
⇓
So এটা দিয়ে কখনও >2m i.e. 3m measure করা যাবে না।

2.2.4 Calibration:

Calibration means development of a definite relationship between water depth and discharge of a flow measuring structure. For broad crested weir 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 $Q = ky_1^n$. The plotting of the calibration equation is known as calibration curve. There are two different ways to develop a calibration equation. They are –

i) Plotting best fit line by eye estimation
ii) 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 line will represent a straight line. So different set of Q 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 h corresponding Q is found from the best fit line. Using these value of h and Q and n the value of K can be found form the equation $Q_a = ky_1^n$. $n = 1.45 - 1.55$

By regression:

$$Q = ky_1^n$$
$$\text{or, } \log Q = \log k + n \log y_1$$

let, $\log Q = Y$, $\log y_1 = X$, $\log k = K$

so, $Y = K + nX$

Then,

$$n = \frac{N(\sum XY) - (\sum X)(\sum Y)}{N(\sum X^2) - (\sum X)^2}$$ where, N=No of data.

and, $$K = \frac{\sum Y - n\sum X}{N}$$

so, k= antilog K

The correlation coefficient r is given by,

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

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

(বাধ্যতামূলক) ⇒ report-এ থাকবে

~~By regression (Should be done by students having even student number):~~

i) For a table having columns Q, y_1, X, Y, XY, X^2 as discussed in article 2.2.4 (Detailed given in calculation portion) and find the value of n, k and r.

ii) Compare the equation formed by eye estimation method.

2.6 Typical shapes of the graph:

Q vs y graph:

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

Actual Discharge vs. Depth of flow graph

$Q = (\ )y^{(\ )}$

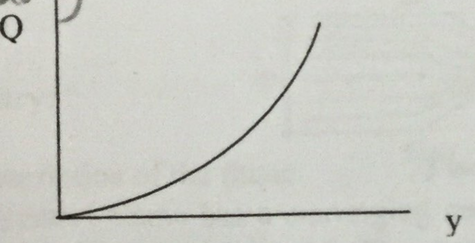
↓

0

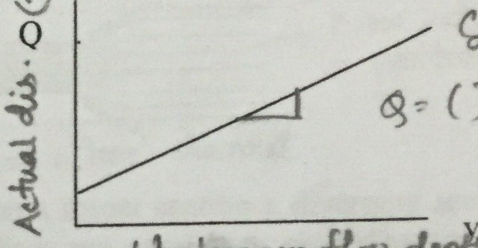
& then any 5 points (random) taken within the depth of flow (y_c)

$n = \dfrac{\log Q_1/Q_2}{\log y_1/y_2}$

Q vs y Graph
(In Plain paper)



Q_a vs y Graph
(In log-log paper)



Upstream flow depth (y), m

n =

K =

C_d =

$Q = (\ )y^{(\ )}$

$\log Q_1 = \log K + n \log y_1$

2.7 Assignment:

→ n measure-এর জন্য যেকোনো point নিব অনুযায়ী থেকে যেকোনো দুইটি point নিব।

⇓

K = determined

1. What are the advantage, disadvantage and uses of broad crested weir?
2. Why is it necessary to calibrate the weir?
3. Broad crested weir designed so that $0.07 \le H_1/L \le 0.5$. What dose the upper and lower limits signify?

$K = C_d (2/3)^{1.5} \sqrt{g} B$ ⇒ from this C_d = determined

2.8 References:

i) Chapter –8 (Flow Measurement), Open Channel Hydraulics-By, Richard H. French

ii) Chapter –12 (Flow measurement), Fluid Mechanics with Engineering Applications-By, Robert L. Daugherty and Joseph B. Franzini

Discussion : H_1/L ratio

vel. এর সাথে discuss করব

Experiment No. 3

Flow Through a Venturi Flume

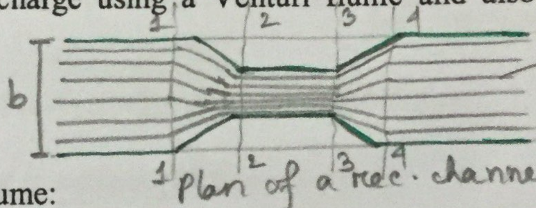
→ open flume i.e. free surface on top

- But venturi flume-1 ⇒ both top & bottom surface 2টো free surface

3.1 General:

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 a dead water zone upstream of the installation which can serve 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 a outlet of canal to supply water in the field or distributory canal. But a Venturi flume has a disadvantage that there is relatively small head difference between upstream section and critical section, specially in low Froude number. This experiment deals with measurement of discharge using a Venturi flume and also calibration of the flume.

particularly in submerged flow condition.



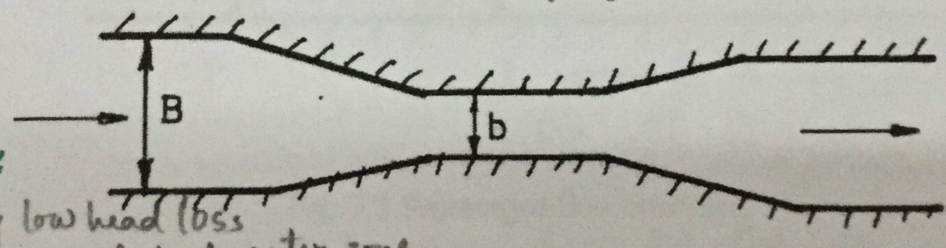
→ Flow pattern through a venturi flume

3.2 Theory:

3.2.1 Description of the flume:

Venturi flume has a converging section a throat section a diverging section. The bed level is kept horizontal. The streamlines run parallel to each other at least over a short distance.

- 3 sections of venturi-flume -
  1. Converging 1-1 to 2-2
  2. Throat 2-2 to 3-3
  3. Diverging 3-3 to 4-4



- Advantage:
  1. Relatively low head loss
  2. No existence of dead water zone

for dead H_2O zone abrupt converging tendency of flow

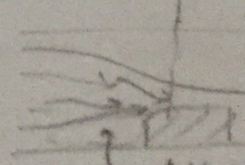


Fig. 3.1 Flow through a venturimeter.

3.2.2 Theoretical discharge in free flow condition:

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,

⊛ free flow condition → tail gate totally open থাকবে i.e. যে flow এর মধ্যে subcritical, supercritical, critical, hydraulic jump এসব overcome করে তারপর flow d/s দিয়ে বের হবে।

$$F = 1 \Rightarrow \frac{v_c^2}{gD_c} = 1 \Rightarrow v_c = \sqrt{gD_c}$$

D_c = Hydraulic depth = $\frac{A}{T} = \frac{by_c}{b}$

$\therefore D_c = y_c$

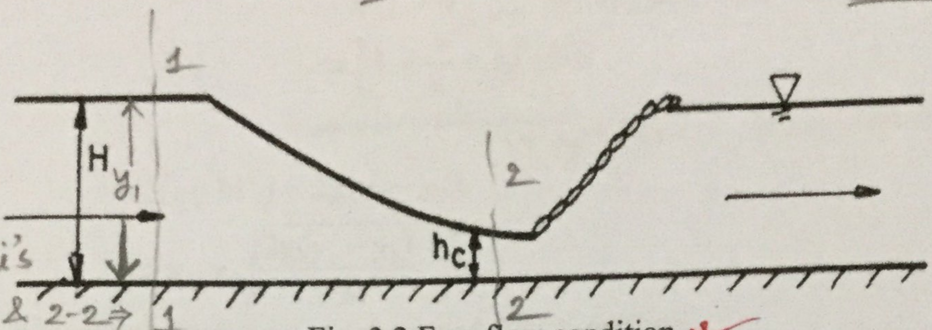


Fig. 3.2 Free flow condition

$\boxed{H = 1.5y_c}$

↓ applying Bernoulli's theorem betn 1-1 & 2-2 ⇒

$H = y_c + \frac{v_c^2}{2g} = y_c + \frac{y_c}{2} = 1.5\,y_c$

⇓ as for rec. channel, $\frac{v_c^2}{2g} = \frac{y_c}{2}$

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 given by,

$$Q_{tf} = A_c V_c = by_c\sqrt{gy_c} \tag{3.1}$$

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

$$Q_{tf} = (2/3)^{1.5}\sqrt{g}\,bH^{1.5} \tag{3.2}$$

where, H = head measured sufficiently upstream of the flume.

3.2.3 Theoretical discharge in submerged flow condition:

⇓ Back H_2O flow ⇒ যেখানে tail gate একটু একটু করে বন্ধ করলে flow বাধা পাবে So যে flow in করবে তা out হতে পারবে না & d/s-এ কিছু H_2O জমা হবে। এই জন্য H_2O এর জন্য Back H_2O flow হবে।

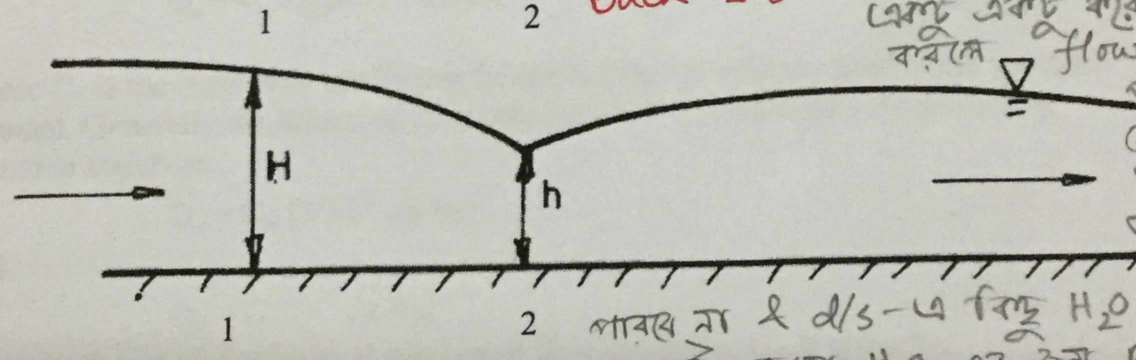


Fig. 3.3 Submerged flow condition

⇓ Back H_2O flow এসে y_c কে submerge করে দিবে

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

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

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

$$\Rightarrow v_2^2(1 - \frac{v_1^2}{v_2^2}) = 2g(y_1 - y_2)$$

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

$$Av_1=av_2$$ flow area at throat section

$$\Rightarrow \frac{v_1}{v_2}=\frac{a}{A}=M \text{ (let)}$$ upstream flow area

So,

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

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

Hence, theoretical discharge, at submerged flow condition

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

3.2.4 Coefficient of discharge:

Due to some assumption taken in the derivation of the 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

$$C_{df}=Q_a/Q_{tf} \qquad (3.4)$$

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,

$$Q_a=C_vC_{df}(2/3)^{1.5}\sqrt{g}\,by_1^{1.5} \qquad (3.5)$$

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

$$Q_a=C_{df}(2/3)^{1.5}\sqrt{g}\,By_1^{1.5} \qquad (3.6)$$

and,

$$Q_{tf}=(2/3)^{1.5}\sqrt{g}\,By_1^{1.5} \qquad (3.7)$$

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

$$C_{ds}=Q_a/Q_{ts} \qquad (3.8)$$

3.2.5 Calibration:

Calibration means development of a definite relationship between water depth and discharge 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 develops the equation

$Q = ky_1^n$. The plotting of the calibration equation is known as calibration curve. There are two different ways to develop a calibration equation. They are –

iii) Plotting best fit line by eye estimation
iv) Developing best fit line by regression

Experiment No. 4

Flow Through A Parshall Flume

↳ Calibrated device → no calibration is needed

4.1 General:

The problem of Venturi flume is there is relatively small head difference between upstream section and critical section, especially in low Froude number. This problem can be alleviated by designing a flume which has a constructed throat section in which critical flow occurs followed by a short length of flume in which supercritical flow occurs. A flume of this type was designed by R.L. Parshall and is widely known as the Parshall flume. Practically this type of flume used in small irrigation canals for flow measurement purpose. It is better than all other devices discussed before as it is more accurate, can withstand a relatively high degree of submergence over a wide range of backwater condition down stream from the structure, and it acts as a self cleaning device due to the fact that high velocity washed out the debris and sediments present in the flow. However when a heavy burden of erosion debris is present in the stream, the Parshall flume become invalid like weir , because deposition of debris will produce undesirable result. Another problem arises with this flume is that the fabrication is tough and also fabrication should be done as per requirement. This experiment deals with the measurement of discharge using Parshall flume.

4.2 Theory:

4.2.1 Description of the flume:

Parshall flume consists of a broad flat converging section, a narrow downward sloping section and an upward sloping diverging section. The reason of downward sloping throat section is to increase the head difference between upstream section and critical section. The upward slope is given in diverging section to produce a high tail water depth which reduces the length of the super critical flow region.

• Converging section ↳ ↑ward slope দেয়া হয় যাতে debris washout হতে পারে & জমা না হয়।

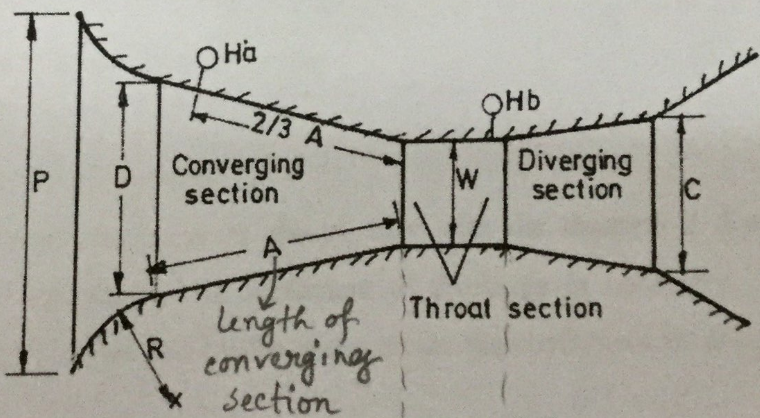
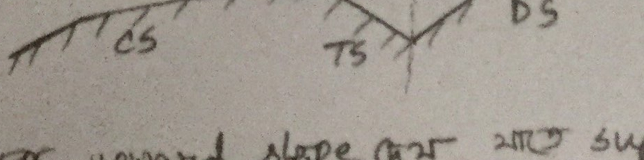


Fig. 4.1 Flow through Parshall flume

• Throat section-এ ↓ward sloping দেয়া হয় so that significant head difference can be got betn u/s & throat section



• Diverging section এর upward slope দেয় যাতে super critical condition কমানোর জন্য tail H_2O depth বাড়িয়ে।

4.2.2 Theoretical discharge:

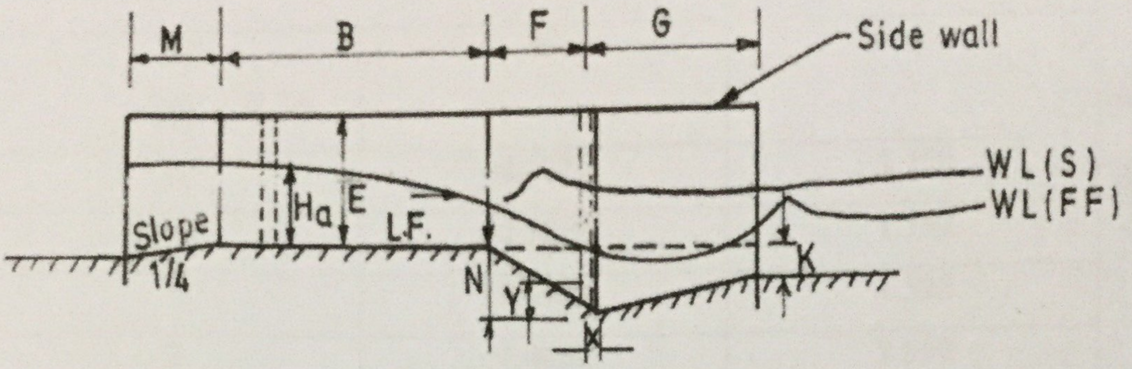


Fig. 4.2 Free flow and submerged flow condition

The Parshall flume is a calibrated device i.e. there exists a definite depth discharge relationship for the flume. So analytic determination of theoretical discharge is not required for this flume. The discharge through a Parshall flume is given by

$$Q_t = KH_a^n \qquad (4.1)$$

where, K = a constant which depends on the system of units used

n = exponent

H_a = upstream depth measured at the location shown in Fig. 4.1

The values of K and n are depend on the throat width and given in Table 4.1. According to this table for free flow condition, the depth-discharge relationship of a Parshall flume of 6" throat width which is normally used in the laboratory, as calibrated empirically, is given by

$$\overset{m^3/s}{Q_{tf}} = 0.3812\, \overset{m}{H_a}^{1.58} \qquad (4.2)$$

where Q_t is in m^3/s and H_a is in meters.

4.2.2 Coefficient of discharge:

The actual discharge is always vary with the theoretical discharge of the flume. So an introduction of coefficient of discharge is necessary. If the actual discharge(Q_a) is measured by the water meter, the coefficient of discharge is given by,

$$C_{df} = Qa/Q_{tf} \text{ (at free flow condition)} \qquad (4.3)$$

$$C_{ds} = Qa/Q_{ts} \text{ (at submerged flow condition)} \qquad (4.4)$$

Table 4.1

Values of K, n for different W

W (ft) ·436	K	n
¼	0.1771	1.550
½	0.3812	1.580
1	0.6909	1.522
2	1.4280	1.550
4	2.9530	1.578
8	6.1120	1.607
20	14.450	1.600
50	35.410	1.600

for this exp. ⇑ 1·572

4.2.2 Percentage submergence: $\checkmark = \frac{100 H_b}{H_a}$

The percentage of submergence for the Parshall flume is given by 100 H_b/H_a, where H_b is the downstream depth from the invert datum.

When the percentage of submergence exceeds 0.6 the flume discharge is reduced. The discharge of Parshall flume then equals

$$Q_{ts} = Q_{tf} - Q_E \qquad (4.5)$$

where, Q_{ts} = corrected discharge due to submergence

Q_{tf} = theoretical free flow discharge

Q_E = correction of discharge as found from the attached figure.

The correction of discharge for a 6 inch Parshall flume is is given in Fig 4.3

4.3 Objectives of the experiment:

i. To determine the theoretical discharge at free flow condition

ii. To determine the theoretical discharge at submerged flow condition.

ii. To determine the value of co-efficient of discharge C_d for both condition.

iii. To verify the value of K and n.

• Disadvantages of Parshall Flume:
① real case-এ throat section-এ bed level slope ↓ward, so বেশির দিকে যেতে থাকে। So real-এ H_2O carries a lot of debris & sediment এই downward-এ settle করে। So এখানে upward slope-এ থাকে তখন total debris carry করে না। So bed level slope has been altered & so sediment deposition ⇒ Fabrication

Experiment No. 5

Flow through a Cut throat flume

5.1 General:

③ Maintain & depreciation cost comparatively high.

Although Parshall flume gives very accurate measurement of discharge but the problem of the flume is that the fabrication of such flume is complicated and also fabrication should be done as per requirement. The cut throat flume is an attempt to improve on the Parshall flume mainly by simplifying the construction details. So the flume is economic and normally used in straight sections of small irrigation channels for flow measuring purpose. The angle of divergence and convergence remain same for all flumes so the size of the flume can be changed by merely moving the vertical walls in or out. This experiment deals with the measurement of discharge using Cut throat flume. ② অনেক গুলি slope & so bed level undulated which is difficult to construct ⇒ Construction Detailing

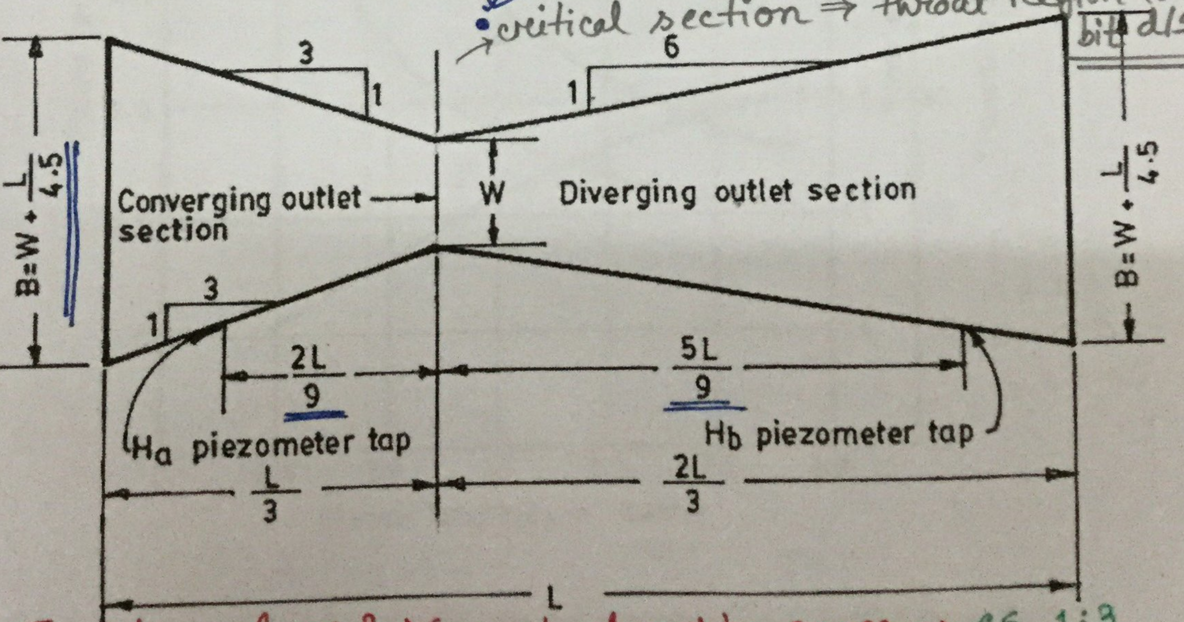
5.2 Theory:

• Advantage of cut throat flume:
1. Construction easy
2. Maintenance & reapairing cost less
3. Provides a sufficient level of flexibility as we can vary the dimen^n of flume

5.2.1 Description of the flume:

The flume has a flat bottom, vertical walls, and a zero length throat section. Since it has no throat section, it was given the name 'Cut throat'. The details of the standard shape of a cut throat flume are shown in Fig 5.1. It can operate either as a free or submerged flow structure. Under free flow condition critical depth occurs in the vicinity of the throat. Any flume length between 45 cm to 3 m can be used while throat widths between 2.5 cm to 1.8 m have been investigated.

• WorldWide 16 types of cut throat flume.
and • the intersection of converging and diverging section will be HINGED.



• The slopes of CS & DS must always be same ⇒ CS 1:3, DS 1:6

Fig. 5.1 Flow through Cutthroat flume

• Disadvantage:
1. Head loss ↑, so C_d ↓ relative to parshall flume
CZ যেহেতু কোন throat section থাকে না। So abrupt convergence & divergence of streamlines increases the head at throat.

Q.1. Why $2L/9$ and $5L/9$ নেয়া হয়?

⇒ for converging section -এ at $2L/9$ distance-এ stream Lines slightly converge করছে। So এখানে নেয়া হয়।

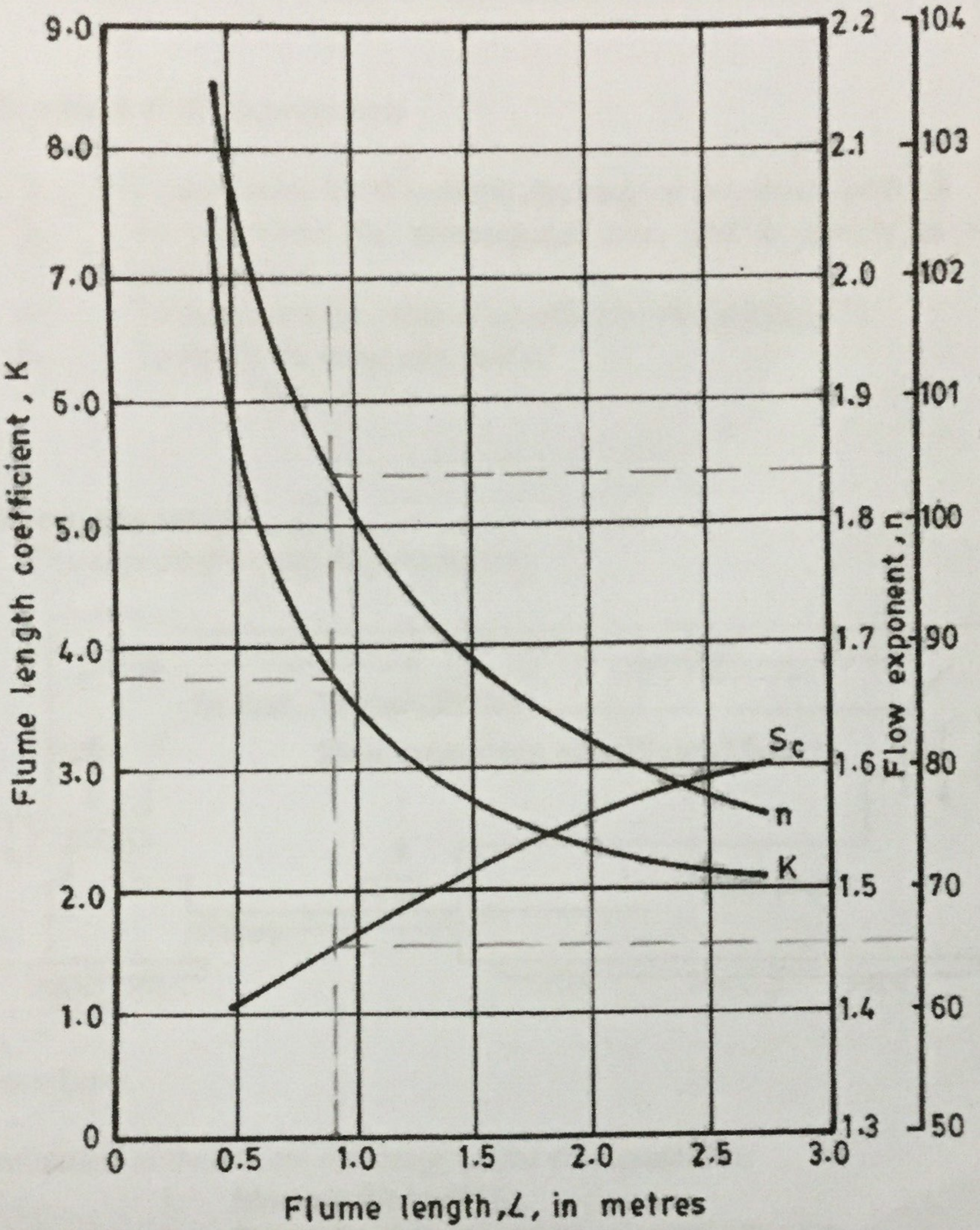
→ for diverging section - $5L/9$ distance লাগে to overcome the critical, supercritical state and hydraulic jump. So $5L/9$ -এ নেয়া হয় measurement cz এর থেকে কাছে velocity & stream Line nature অনেক বেশি vary করবে?

Q.2. $Q_a = KH_a^n$ where H_a = u/s head. why u/s head?

— We want the inflow discharge through all the devices. d/s-এ vel. অনেক বেশি vary করে। So calibrate করা হয় u/s head দিয়ে cz u/s velocity কম vary করে।

where, C	= free flow coefficient given by, $C=KW^{1.025}$	(5.2)
K	= the flume length coefficient	
W	=the width of the throat	
n	= flow exponent	
H_a	= upstream flow depth (measured at a distance of 2L/9 form the throat, shown in Fig. 5.1)	

The values of K and n are obtained from Fig.5.2 for a given flume length.



L = 0·9m
n = 1·84
K = 3·8
S = 0·66

Fig. 5.2 Generalized free flow coefficients and exponents and S_t for Cut-throat flume.

- Range of L = 0·45 – 2·8
  & W = ·025 – 1·8

All the 16 types of Flumes are within this range.
So graph-এই range-এর ভিতরেই আসবে।

5.2.3 Submergence ratio and submerged flow condition:

In order to ensure free flow conditions the ratio between the water depth at the exit and entrance i.e. submergence ratio (H_b:H_a) should not exceed a certain limit, called the transition submergence, S_t which can be determined by Fig. 5.2. If the submergence ration exceed the transition submergence the flow condition will said to be submerged flow condition.

$\frac{H_b}{H_a} > S_t \Rightarrow$ Submerged flow

otherwise $\Rightarrow$ Free flow

5.2.4 Coefficient of discharge

The actual discharge is always vary with the theoretical discharge of the flume. So an introduction of coefficient of discharge is necessary. If the actual discharge(Q_a) is measured by the water meter, the coefficient of discharge is given by,

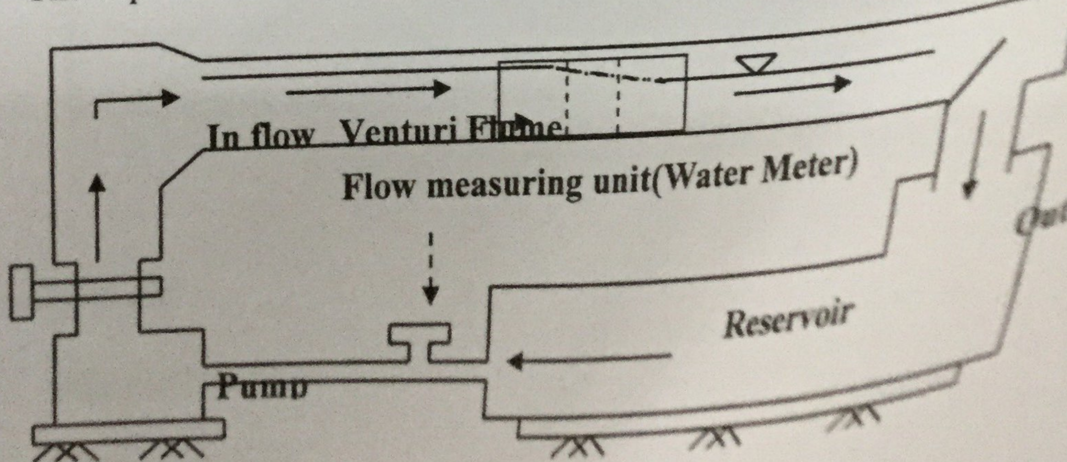
$$C_{df} = Qa/Q_{tf} \text{ (at free flow condition)} \qquad (5.3)$$

5.3 Objectives of the experiment:

i. To determine the theoretical discharge at free flow condition
ii. To determine the submergence ratio and to check the effect of submergence
iii. To determine the value of co-efficient of discharge Cd.
iv. To verify the value of C and n.

5.4 Experiment setup:

The experiment setup is given below.



5.5Procedure:

Determination of theoretical discharge at free flow condition:

i. *Measure the head H_a.*
ii. *Determine the value of K and n from Fig 5.2*
iii. *Determine value of C using Eq.(5.2)*
iv. *Determine the theoretical discharge from Eq.(5.1)*

Determination of the subm