MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF EWCE

EWCE 362: Open Channel Hydraulics Sessional

Experiment No. 7

Development and generalized specific energy and specific force curves

7.1 General

The concept of specific energy and specific force is extremely useful in the solution of many problems in open channel flow. This experiment deals with the development of generalized specific energy and specific force curves. These curves are useful in determining the state of flow in a channel, i.e. whether the flow is critical, subcritical or supercritical. Flow is critical when the Froude number is equal to unity. When the depth of flow is above the critical depth, the subcritical state of flow exists in the channel. When the depth of flow is below the critical depth, the supercritical state of flow exists. Also, the critical state of flow gives us several important conditions, such as, the specific energy and specific force are minimum for a given discharge, the discharge being maximum for a given specific energy and so on. All these conditions are used in designing the various types of transitions and in controlling the flow using different control structures, for example, in determining the height of a weir, the width of a flume, the opening of a sluice gate, etc.

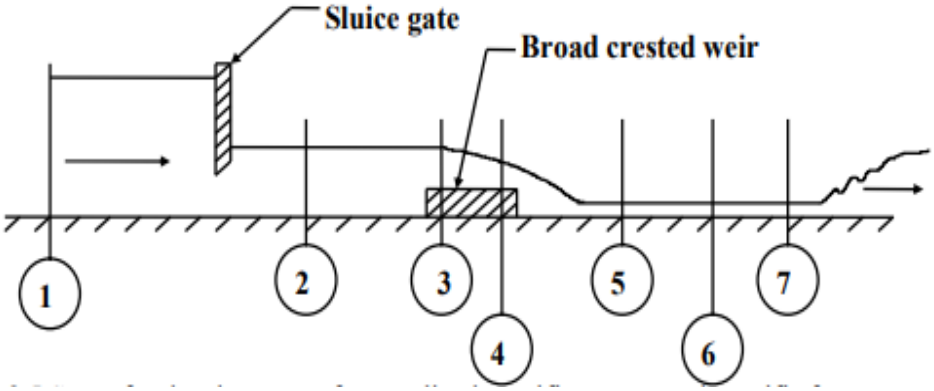


Fig. 7.1 Setup for development of generalized specific energy and specific force curves

7.2 Theory

7.2.1 Specific energy:

Specific energy is defined as the energy per unit weight of water at any section of a channel measured with respect to the channel bottom. If the total energy at any section is given by,

$$H = z + y + v^2/(2g) \qquad (7.1)$$

Then the specific energy at any section of a channel is obtained by putting z = 0

i.e. $E = y + v^2/(2g)$ (7.2)

Since Q=Av, Eq. (7.2) can be written as
$E = y + Q^2/(2gA^2)$ (7.3)

For a rectangular channel, A = by, so Eq. 7.3 can be written as,

$E = y + Q^2/(2gb^2y^2)$ (7.4)

7.2.2 Specific Energy Curve

For a given channel section and discharge, the specific energy is a function of the depth of flow. When the depth of flow is plotted against the specific energy, a specific energy curve is obtained. This curve has to limbs CA and CB (fig 7.1). From Eq. 7.4 it can be seen that at $y \rightarrow 0, E \rightarrow \infty$, so that the limb CA approaches the horizontal axis asymptotically towards the right. Now at $y \rightarrow \infty$, $E \rightarrow \infty$, so that $v^2/(2g) \rightarrow 0$ and $E \rightarrow y$, which implies that the limb CB approaches the E = y line (line OD) asymptotically. As the slope of E = y line is 1 so it has an inclination of 45° with the horizontal axis and it passes through the origin.

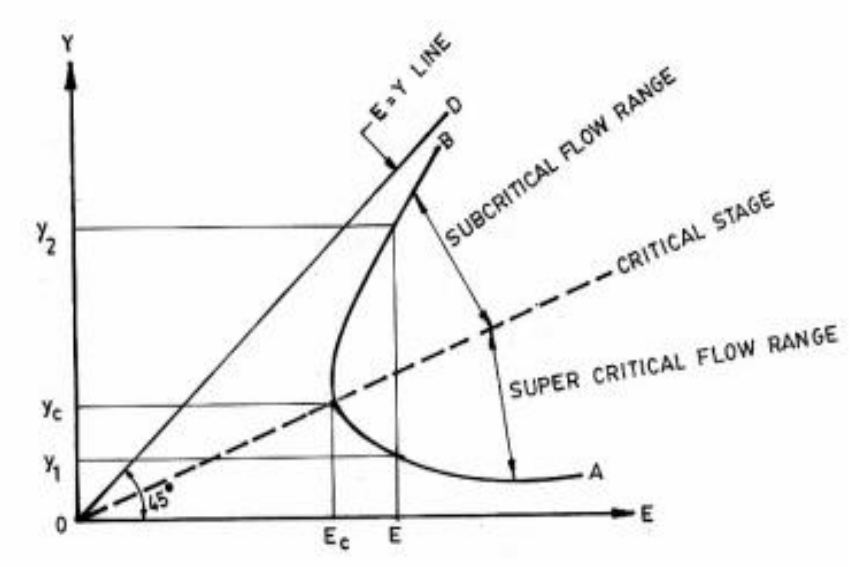


Figure: 7.2 Specific- energy curve

The specific energy curve (Fig 7.2) shows that, for a given specific energy, there are two possible depths, the low stage y_1 and the high stage y_2 which are called alternate depth of each other.

Differentiating Eq.7.3 with respect to y and simplifying, we obtain,

$dE/dy = 1 - v^2/(gD)$ (D = Hydraulic depth)

At point C, the specific energy is minimum, so at C

$dE/dy = 0$

so that $v^2/(gD) = 1$

$F_r^2 = 1$

$F_r = 1$

This condition represents critical state of flow. At this condition, the two alternate depths apparently become one which is known is the critical depth y_c. When the depth of flow is greater than y_c, the velocity of flow is less than the critical velocity for the given discharge and hence the flow is subcritical. When the depth of flow is less than the critical depth, the flow is supercritical. Here y_1 is the depth of supercritical flow and y_2 is the depth of subcritical flow.

7.2.3 Generalized specific energy curve:

If the discharge changes the specific energy curve will be change accordingly i.e. the curves moves to right if the discharge is increased and vice versa. In order to develop a generalized specific energy curve i.e. to use one specific energy curve for different discharges, the curve is to be made dimensionless with respect to the critical depth as the critical depth as the critical depth y_c is constant for a given discharge. So dividing both sides of Eq. (7.4) by y_c and after simplification, we obtain

$E/y_c = y/y_c + (1/2)(y_c/y)^2$ (7.5)

Eq. (7.5) is the generalized from of the relationship between specific energy and depth of flow in which each term is discharge is dimensionless.

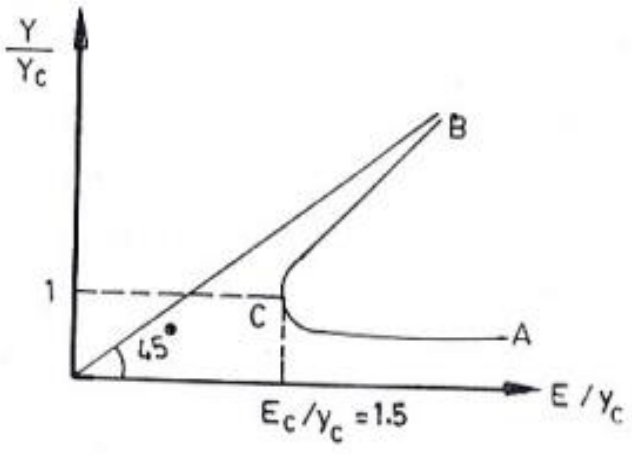


Figure: 7.3 Dimensionless specific energy curve

7.2.4 Specific force:

Specific force is defined as the force at any channel section which is equal to the sum of the hydrostatic force and momentum of the flow passing the section per unit time. For a rectangular channel the specific force is given by,

$F = (1/2)\,\rho g b y^2 + \rho Q^2/(by)$ (7.6)

7.2.5 Specific force curve:

For a given discharge and cross section, the specific force F is a function of the depth of flow y only. Plotting the depth of y flow vs. the specific force F produces specific force curve (Fig 7.4). This curve has two limbs CA and CB. At $y \rightarrow 0$, $F \rightarrow \infty$, So the limbs CA approaches the horizontal axis asymptotically towards the right. Now, at $y \rightarrow \infty$, $F \rightarrow \infty$, but at this condition F becomes proportional y^2. So the limbs CB rise upward and extend infinity towards right.

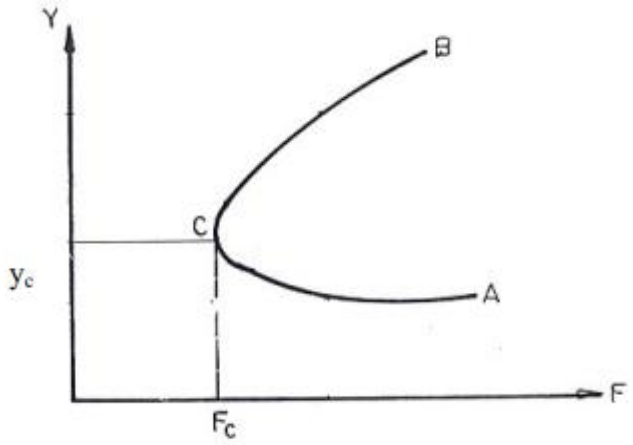


Figure: 7.4 Specific force curve

The curve shown that, for a given specific force, there are two possible depths, y_1 and y_2. These two depths constitute the initial and sequent depths of a hydraulic jump. Differentiating eq. 7.6 with respect to y and simplifying, we get

$dE/dy = \rho gA - \rho Q^2/(AD)$

At point C, the specific force is minimum, so at C

$dF/dy = 0$

$\rho gA = \rho Q^2/(AD)$

$Q^2/(gDA^2) = 1$

$V^2/(gD) = 1$

So that $F_r^2 = 1$

$F_r = 1$

Which is the same criteria developed for the minimum value of specific energy. Therefore, for a given discharge, minimum specific force occurs at minimum specific energy or at the critical state of flow.

7.2.6Generalized specific force curve:

If the discharge changes, the specific energy will be change accordingly i.e. the specific force curve moves to right if the discharge is increased and vice versa. In order to develop a generalized specific force curve, i.e. to use one specific force curve for different discharges the curve is to be made with respect to the critical depth as the critical depth y_c is constant for a given discharge. So dividing both sides eq. 7.6 by $y_c^2\rho gb$ and after simplification, we obtain

$$F/(y_c^2\rho gb) = y_c/y + (1/2)(y/y_c)^2 \quad (7.7)$$

Eq. 7.7 is the generalized specific force equation and each term of this equation is dimensionless. The plot of this equation is shown in Fig 7.5.

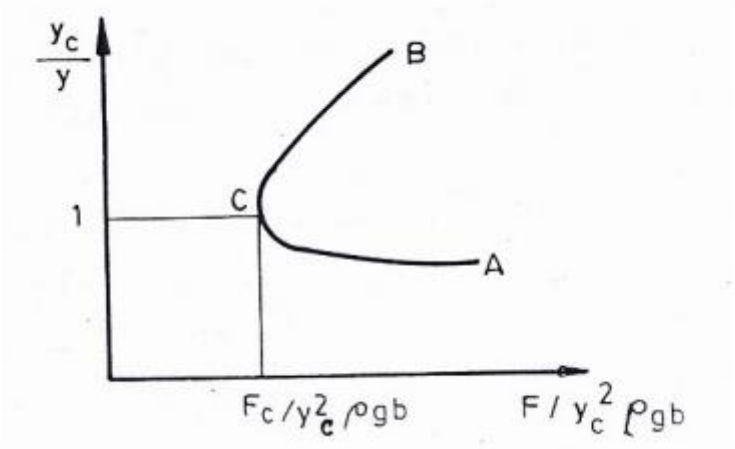


Figure: 7.5 Dimensionless specific force curve

7.3 Objectives

1. To observe the flow profile in the experimental setup which depicts the variation of depth with change in energy.
2. To plot the generalized specific energy and specific force curves from observed data.

7.4 Experiment setup

To plot the generalized specific energy and specific force curves we have to observe the response of sub critical (slow) and supercritical (fast) flows to changes in the energy and force of a stream. For this, the setup as in fig. 7.6 can be used.

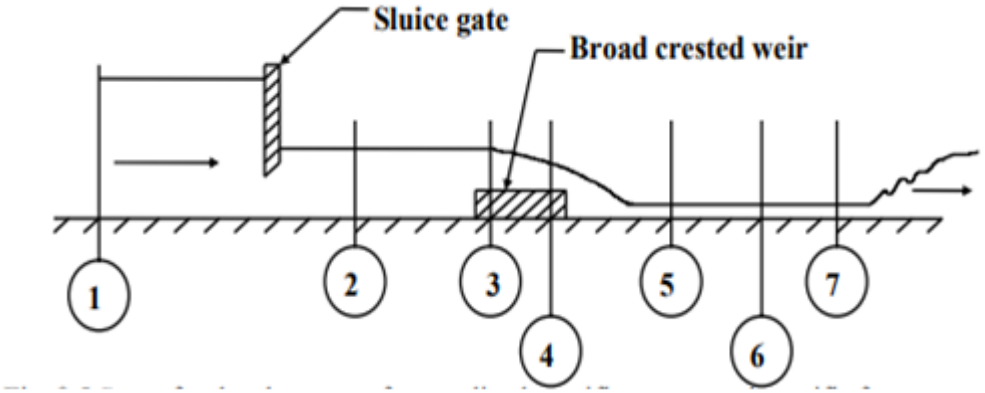


Figure: 7.6 Setup for development of generalized specific energy and specific force curve

7.5 Procedure

1. Determine depth of flow at three points as shown in Fig. 7.6 in each of the sections 1 to 7. Find the average depth for each section.
2. Determine the actual discharge from water meter and compute y_c.
3. Compute E/y_c and $F/(y_c^2\ \rho gb)$ for each of the sections using eq. 7.5 and 7.7 respectively.
4. Plot y/y_c vs. E/y_c and y/y_c vs. $F/\ (y_c^2 \rho gb)$ on plain graph papers to get the generalized specific energy and specific force curves.

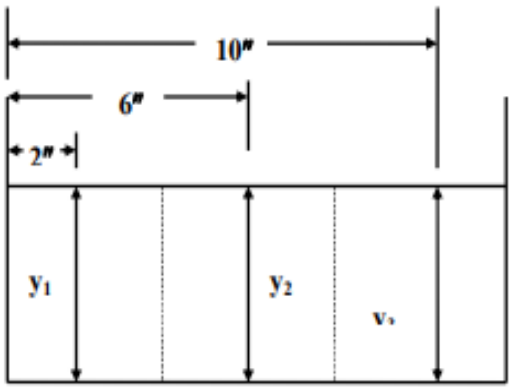
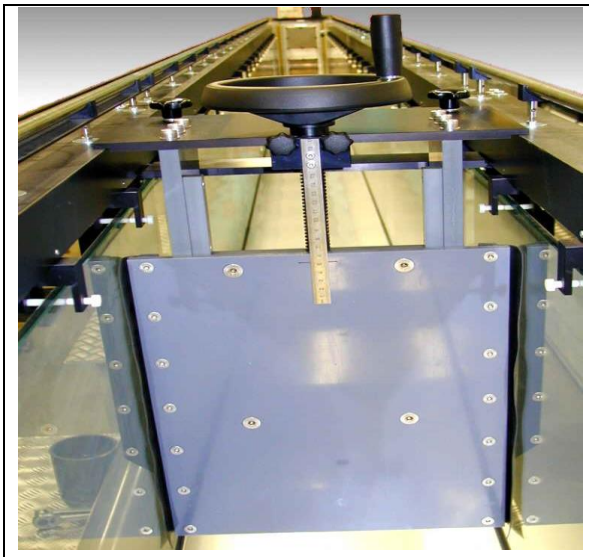
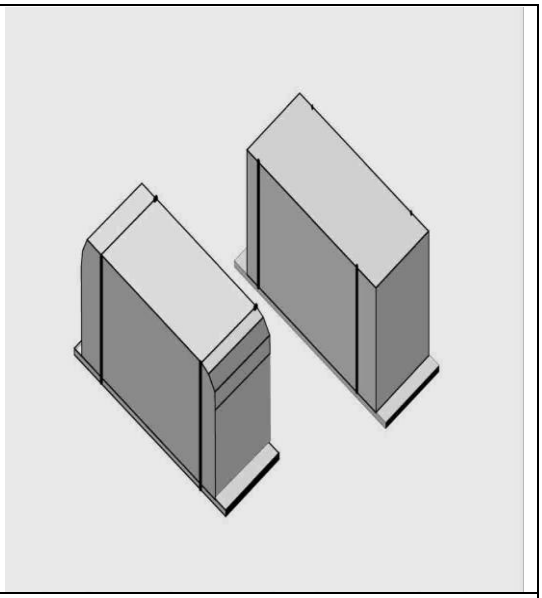
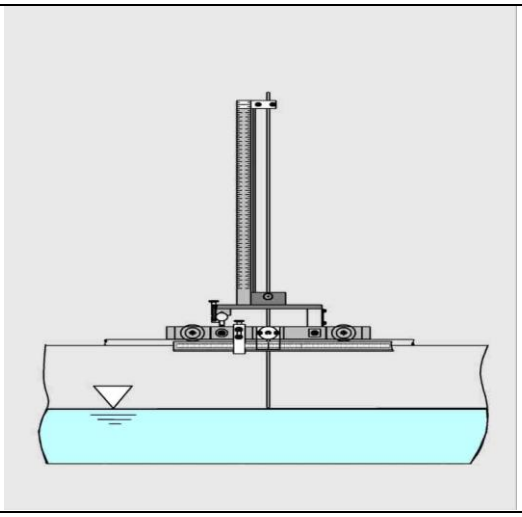


Figure: 7.7 Locations for measuring the depths

7.6 Apparatus

	
Sluice Gate	**Broad crested weir**
	
Flow Channel	**Instrument carriage**

DATA SHEET

Development and generalized specific energy and specific force curves

$Q =$ m^3/s $b =$ m $y_c = (Q^2/gb^2)^{1/3} =$ m

Section	y_1 (m)	y_2 (m)	y_3 (m)	$y = (y_1+y_2+y_3)/3$	E (m)	F(N)	y/y_c	E/y_c	$F/(y_c^2\rho gb)$
y_1									
y_2									
y_3									
y_4									
y_5									

Level / Term : **Dept. :**

Reg No. : **Section:**

Group No. : **Date :**

Signature of the Teacher

7.8 Calculation

7.9 Discussion

Comments on result:

Comments on graph:

Sources of error:

7.10 Assignment

1. How can you apply the dimensionless specific energy and specific force curve for computing specific energy and specific force for different discharge?

2. How can you use the dimensionless specific energy to find the specific force and vice versa? Explain.