9.3 Application of Specific Force and Specific Energy

1. Determine the energy Loss in a NHJ

Solution:

Applying Momentum equation

$$\frac{\gamma Q}{g}\left(V_2 - V_1\right) = P_1 - P_2$$

$$\frac{\gamma Q^2}{gb^2}\frac{\left(y_1 - y_2\right)}{y_1 y_2} = \left(y_1^2 - y_2^2\right)$$

$$\frac{Q^2}{2gb^2} = \frac{\left(y_1 + y_2\right) y_1 y_2}{4}$$

$$\frac{Q^2}{b^2} = q^2$$

$$\frac{q^2}{2g} = \frac{\left(y_1 + y_2\right) y_1 y_2}{4} \qquad (1)$$

Specific energy equation

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} + \Delta E$$

$$\Delta E = y_1 + \frac{Q^2}{2gy_1^2 b^2} - y_2 - \frac{Q^2}{2gy_2^2 b^2}$$

$$\Delta E = \left(y_1 - y_2\right) + \frac{q^2}{2g}\left[\frac{1}{y_1^2} - \frac{1}{y_2^2}\right]$$

$$= \left(y_1 - y_2\right)\left[1 + \frac{q^2}{2g}\frac{1}{y_1^2 y_2^2}\left(y_2 + y_1\right)\left(-1\right)\right]$$

Substituting from momentum equation

$$= \left(y_1 - y_2\right)\left[1 + \frac{\left(y_2 + y_1\right) y_1 y_2}{4}\frac{\left(y_2 + y_1\right)\left(-1\right)}{y_1^2 y_2^2}\right]$$

$$= \frac{\left(y_1 - y_2\right)}{4 y_1 y_2}\left[4 y_1 y_2 - \left(y_1 + y_2\right)^2\right]$$

$$= \frac{\left(y_1 - y_2\right)}{4 y_1 y_2}\left[4 y_1 y_2 - y_1^2 - y_2^2 - 2 y_1 y_2\right]$$

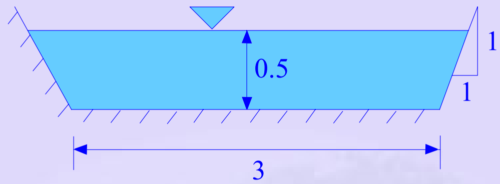
$$\Delta E = \frac{\left(y_2 - y_1\right)^3}{4 y_1 y_2}$$

2. Problem of specific force

Determine the sequent depth in a trapezoidal channel of 3 m width. The initial depth is 0.5 m.

The side slope is 1:1. Initial flow velocity is 4 m/s.

Solution:



$$A = (b+my)y$$

$$\frac{(b+my)y}{b+2\sqrt{m^2+1}\,y} = R$$

$$Q = A.v =$$

$$= (3+0.5)\,0.5*4$$

$$= \frac{3.5}{2}*4 = 7\ m^3/s$$

$$M_1 = \frac{Q^2}{gA} + \bar{z}A$$

$$= \frac{7^2}{9.81*\frac{3.5}{2}} + \left(\frac{3*0.5^2}{2} + \frac{1*0.5^3}{3}\right)$$

$$= 2.86 + 1.5*0.25 + 0.041666 = 3.2767 m^3$$

$$M_1 = M_2$$

$$M_1 = \frac{7^2}{9.81*(3+y_2)\,y_2} + \left(\frac{3*y_2{}^2}{2} + \frac{2}{3}y_2{}^3\right)$$

Solve by trial and error $y_2 = 1.05$m.

Alternative approach is:

$$\frac{\bar{z}\,M_1}{b^3} = \frac{1*3.2767}{3^3} = 0.12135$$

$$\frac{m^2Q^2}{gb^5} = \frac{1*7^2}{9.81*3^5} = 2.05\times10^{-2}$$

From graph $y_2 = 1.05$m.

9.3.1 Hydraulic Jump

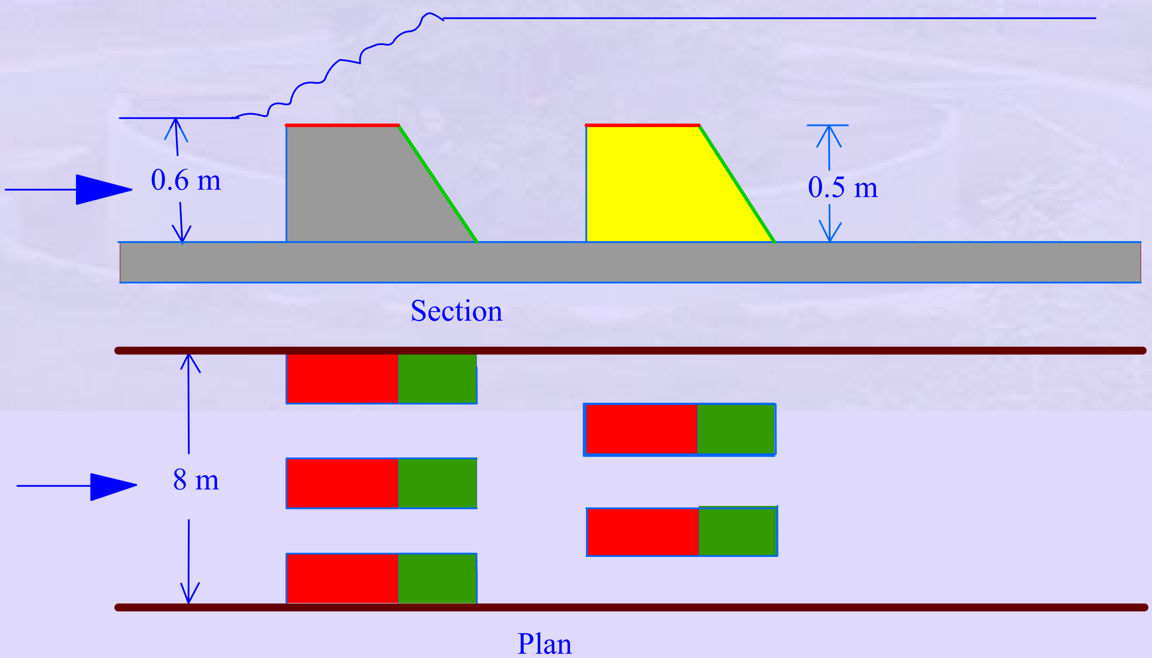
1. For the case of hydraulic jump in a rectangular channel, complete the following table.

y_1 (m)	$\overline{V}_1$ (m /s)	q (m3 /s)	y_2 (m)	$\overline{V}_2$ (m / s)	Head loss (m)
0.20			1.204		
			2.50	1.00	
1.91	26.18	50			

2. A hydraulic jump occurs in a rectangular channel and the depths of flow before and after the jump are 0.50 m and 2.0 m respectively. Calculate the critical depth and the energy loss in the jump.

3. Two rows of baffle piers are to be installed in a stilling basin as shown in the figure in order to assist the formation of the hydraulic jump with in the basin. It is found that such an arrangement of blocks has an effective drag coefficient 0.3, based on the upstream velocity and on the combined frontal area of the blocks. If the discharge is 50 m^3/s and the upstream depth is 0.6 m, find the downstream depth required to form a jump,

(a) If the baffle blocks are installed and (b) if they are not (c) In each case find the head loss in the jump.



Stilling basin

4. A rectangular channel 6m wide carries 11.5 m^3/s and discharges onto a 6m wide apron with no slope with the mean velocity of 6.0 m/s. what is the height of the hydraulic jump? What energy is absorbed (lost) in the jump?

5. A rectangular channel 5m wide carries a flow of 6 m^3/s. The depth of water on the downstream side of the hydraulic jump is 1.30 m. (a) What is the depth at upstream? (b)What is the loss of head?

6. After flowing over concrete spillway of a dam, 254.7 m^3/s then passes over a level concrete apron (n = 0.013). The velocity of the water at the bottom of the spillway is 12.8 m / s and width of the apron is 54.86 m. Conditions will produce a hydraulic jump, the depth in the channel below the apron being 3.05 m. In order that the jump be contained on the apron, (a)How long the apron should be built? (b)How much energy lost from the toe of the spillway to the downstream side of the jump?

7. Starting from first principles, show that the following equation holds true for a hydraulic jump in a trapezoidal channel.

$$\rho g\left[\frac{b\,y^2}{2}+\frac{my^2}{3}\right]+\frac{Q^2\rho}{(\,b+my\,)y}=\text{Constant}$$

Draw the force-momentum diagram for the following conditions and determine the initial depth if the sequent depth is 0.2 m.

Q = 50 l / s; b = 0.46 m; m = 1.

8. A flow of 2.8 m^3/s occurs in a circular channel of 1.8 m in diameter. If the upstream depth of flow is 0.60 m, determine the downstream depth which will cause a hydraulic jump.

9. A flow of 100 m^3/s occurs in a trapezoidal channel with side slopes of 2:1 and a base width of 5m. If the upstream depth of flow is 1.0 m, determine the downstream depth of flow which will cause hydraulic jump.

10. A hydraulic jump occurs downstream from a 15 m wide sluice gate. The depth is 1.5 m, and the velocity is 20 m /s. Determine

(a) The Froude number and the Froude number corresponding to the conjugate depth, (b) the depth and velocity after the jump, and (c) the power dissipated by the jump.

11. A 10 m wide rectangular channel is carrying a discharge of 200 m^3/s at a flow depth of 5 m.

(i) If the channel bottom has sudden rise of 0.3 m determine the depth of flow at a downstream cross section. Does the water surface rise or drop?

(ii) Compute the depth of flow at a downstream section if the drop is 0.2 m

12. An 8 m wide rectangular channel has a flow velocity and flow depth of 4 m/s and 4 m respectively. The channel bottom is at El. 700 m. Assuming no losses, design a transition so that the water level downstream of the transition is at El. 703.54 m, if

(i) The channel width remains constant, and

(ii) The channel bottom level downstream of transition is at El. 700.2 m.

13. A hydraulic jump is formed in a 4 m wide outlet just downstream of the control gate. The flow depths just upstream and downstream of the gate are 20 m and 2 m respectively. If the outlet discharge is 40 m^3/s determine

(i) Flow depth at downstream side

(ii) Thrust on gate

(iii) Energy losses in the jump

Assume there is no loss in the flow through gate.