3.3 HYDRAULIC JUMPS – TYPES

Based on Froude number (F), hydraulic jump can be classified into 5 types.

a. **Undulation jump**: The Froude number F ranges from 1 to1.7 and the liquid surface does not rise shortly but having undulations of radically decreasing size.

b**. Weak jump**: The Froude number F ranges from1.7 to 2.5 and the liquid surface remains smooth.

c. **Oscillating jump**: The Froude number F ranges from 2.5 to 4.5 and there is an oscillating jet which enters the jump bottom and oscillating to the surface.

d. **Steady jump**: The Froude number F ranges from 4.5 to9 and energy loss due to steady jump in between 45 and 70%.

e. **Strong jump**: The Froude number greater than 9 and the downstream water surface is rough. Energy loss due to strong jump may be up to 85%.

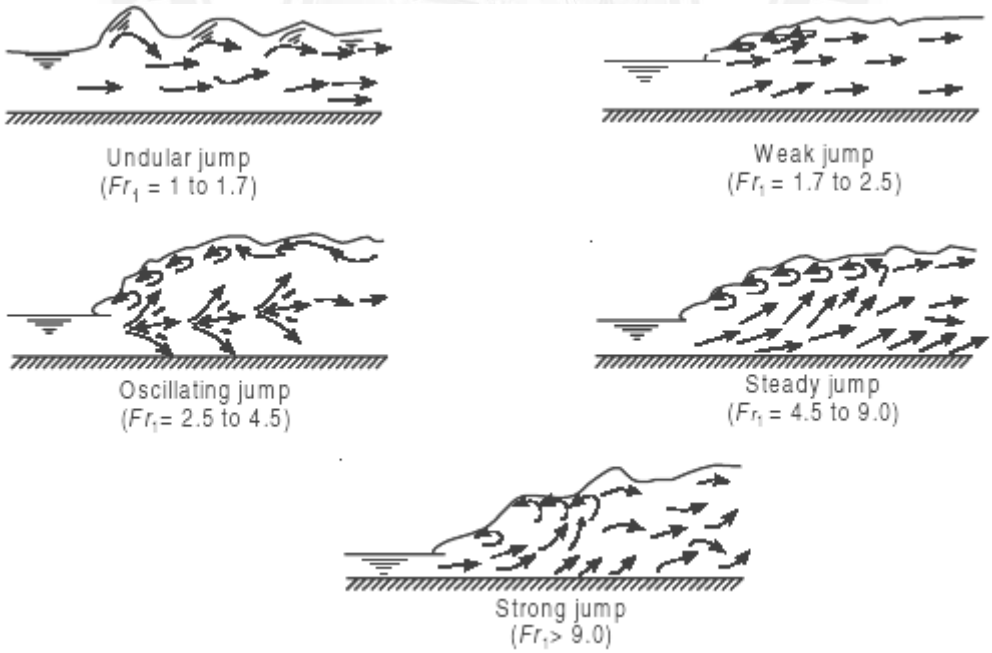

Figure 3.3 Types of hydraulic jump

[*Source: Hydraulics And Fluid Mechanics Including Hydraulic Machines By Dr. P.N.Modi , page 804*]

APPLICATION OF HYDRAULIC JUMP.

1. Generally, the use of hydraulic jump reverses the flow of water. The hydraulic jump can be used to mix chemicals for pure water.
2. It usually maintains a high water level on the downstream side. It is used for high-level water for irrigation purposes.
3. It can be used to remove the sewage lines to prevent air locking and air from a water supply.
4. hydraulic jump prevents the scouring action dam structure on the downstream side.

Problem 1

The depth of flow of water certain section of a rectangular channel of 4m wide in 0.5m.The discharge through the channel in $16m^3/s$ .If a hydraulic jump takes place on a down stream side.find the depth of flow after the jump

Given data:

b= 4m

$Y_1 = 0.5$ m

Q= $16m^3/s$

To find :

Depth of flow after the jump ?

Solution :

$$Y_2 = -\frac{y1}{2} + \sqrt{\frac{y_1{}^2}{4} + \frac{2q^2}{gy_1}}$$

V = q/y q = vy

q= Q/b = 16/4 = 4 m^2/s

$$Y_2 = -\frac{0.5}{2} + \sqrt{\frac{0.5^2}{4} + \frac{2\times4^2}{9.81\times0.5}}$$

$$=2.3163 \text{ m}$$

Result :

$$y_2 = 2.316 \text{ m}$$

Problem 2

The depth of flow of water at a certain section of a rectangular channel of wide in 0.3m.The discharge through the channel in 1.5 m^3/s ,determine whether a hydraulic jump will occur and if so,find its height and loss of energy per kg of water

Given data :

$b = 2m$

$Y_1 = 0.3$ m

$Q = 1.5m^3/s$

To find :

i) Hydraulic jump will occur =?

ii)Height = ?

iii) loss =?

solution :

$$y_c = (q^2/g)^{1/3}$$

where $q = Q/b = 1.5/2 = 0.75\ m^2/s$

$$y_c=(0.75^2/9.81)^{1/3}= 0.385 \text{ m}$$

hence $y < yc$

hydraulic jump will occur

Height of hydraulic jump $= y_2 - y_1$

$$Y_2 = -\frac{y1}{2} + \sqrt{\frac{y_1{}^2}{4} + \frac{2q^2}{gy_1}}$$

$$Y_2 = -\frac{0.3}{2} + \sqrt{\frac{0.3^2}{4} + \frac{2*0.75^2}{9.81*0.3}}$$

$$Y_2 = 0.4862 \text{ m}$$

Height of hydraulic jump

$$= 0.4862 - 0.3$$

$$= 0.1862 \text{ m}$$

Loss of energy

$$h_L = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

$$= \frac{(0.4862 - 0.3)^3}{4 \times 0.4862 \times 0.3}$$

$$h_L = 0.011 \text{ m}$$

Problem 3

A sluice gate discharge water into the horizontal rectangular channel with a velocity of 10m^3/s and the depth of flow of 1m.Determine the depth of flow after the jump and consequent loss in total.

Given data :

$$V = 10 \text{ m/s}$$

$$y_1 = 1\text{m}$$

To find :

$$y2 = ?$$

$$h_L = ?$$

Solution :

$$Y_2 = -\frac{y1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2y_1v^2}{g}}$$

$$Y_2 = -\frac{1}{2} + \sqrt{\frac{1^2}{4} + \frac{2\times1\times10^2}{9.81}}$$

$$= 4.043 \text{ m}$$

Loss of energy

$$h_L = \frac{(y_2-y_1)^3}{4y_1y_2}$$

$$= \frac{(4.043-1)^3}{4\times4.043\times1}$$

h_L = 1.742m

Problem 4

A hydraulic jump form at the down stream end of spillway carrying 17.73m^3/s discharge.if the depth before jump is 0.80m.determine the depth after the jump and energy loss

Given data :

$$Q = 17.93 \text{ } m^3/s$$

$$Y_1 = 0.8$$

To find :

$$y_2 = ?$$

$$h_L = ?$$

Solution :

$$q = Q/b$$

Take b = 1m

$$Y_2 = -\frac{y1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}$$

$$Y_2 = -\frac{0.8}{2} + \sqrt{\frac{0.8^2}{4} + \frac{2\times 17.73^2}{9.81*0.8}}$$

$$= -0.4 + 8.5912$$

$$y_2 = 8.66 \text{ m}$$

$$h_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

$$= \frac{(8.1912 - 0.8)^3}{4\times 0.8\times 8.1912}$$

h_L = 17.52 m

Problem 5

A control sluice in spanning the entry of 4m wide rectangular channel having a mild slope at mid $16m^3/s$ at a velocity of 3m/s .find whether a hydraulic jump is expected in the channel downstream from the sluice

Given data :

b = 4m

Q = 16 m^3/s

V = 3 m/s

To find

Hydraulic jump will occur or not

Solution

$Y_c = (q^2/g)^{1/3}$

$q = Q/b$

$=16/4$

$= 4\ m^2/s$

$yc = (4^2/9.81)^{1/3}$

$= 1.177$ m

$V = Q/A$

$= Q/b \times y = q/y$

$3 = 4/y$

$y = 4/3 = 1.33$ m

$y > yc$

Hydraulic jump is not expected

Problem 6

Water flows at the rate of 1×10^6 cm^3/s along a channel of rectangular section 1.75 m in width.calculate the critical depth if a hydraulic jump formed at a point where the upstream depth is 25cm.what would be the raise in water level and power lost in jump.

Given data :

$Q = 1 \times 10^6 cm^3/s$

$= 1 \times 10^6 \times (10^{-2})^3 m^3/s$

$= 1 \times 10^6 \times 10^{-6} m^3/s = 1\ m^3/s$

$b = 1.75$ m

$y_1 = 25$ cm $= 0.25$ m

To find

critical depth = ?

Raise in water level y_2 = ?

Power lost = ?

Solution

$Y_c = (q^2/g)^{1/3}$

$q = 1/1.75 = 0.5714\ m^2/s$

$Y_c=(0.5714^2/9.81)^{1/3}$

$Y_c= 0.3217$ m

Here $Y < Yc$

Hydraulic jump will occur

$$Y_2 =-\frac{y1}{2} + \sqrt{\frac{y_1{}^2}{4} + \frac{2q^2}{gy_1}}$$

$$Y_2 =-\frac{0.25}{2} + \sqrt{\frac{0.25^2}{4} + \frac{2\times0.5714^2}{9.81\times0.25}}$$

$=0.40589$ m

Height of hydraulic jump

$=y_2 - y_1$

$=0.40589 - 0.25$

$= 0.15589$m

Loss of energy

$$h_L =\frac{(y_2-y_1)^3}{4y_1y_2}$$

$$= \frac{(0.405-0.25)^3}{4\times0.25\times0.405}$$

$= 9.33\times10^{-3}$

Power lost

$P = \rho g Q h_L$

$= 1000\times 9.81 \times 9.33\times10^{-3}$

$= 91.523$ w