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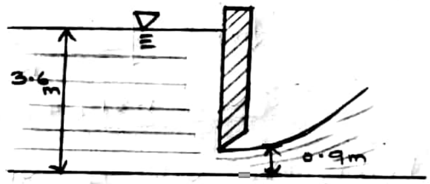
Assignment # 3

Problem

Given Data:-

Depth of water at upstream side (y_1) = 3.6m
Depth of water at downstream side (y_2) = 0.9m
Width of sluice gate (b) = 3.9m

Solution:-



As we know that Specific Energy on both streams are Same
So,

$$E_1 = E_2$$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \quad \text{——— ①}$$

Also By discharge formula,

$$Q = A_1 V_1 = A_2 V_2$$

$$b_1 y_1 \cdot V_1 = b_2 y_2 \cdot V_2$$

$$b \cdot y_1 \cdot V_1 = b \cdot y_2 \cdot V_2 \qquad (\because b = b_1 = b_2)$$

$$y_1 \cdot V_1 = y_2 \cdot V_2$$

$$\Rightarrow V_2 = \frac{y_1}{y_2} \times V_1$$

$$= \frac{3.6}{0.9} \times V_1 \Rightarrow \boxed{V_2 = 4V_1} \text{ ——— ②}$$

Putting the value of V_2 in eq ①,

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

$$3.6 + \frac{V_1^2}{2g} = 0.9 + \frac{(4V_1)^2}{2g}$$

$$3.6 + \frac{V_1^2}{2g} = 0.9 + \frac{16V_1^2}{2g}$$

$$\frac{v_1^2}{2g} - \frac{16v_1^2}{2g} = 0.9 - 3.6$$

$$\frac{v_1^2 - 16v_1^2}{2g} = -2.7$$

$$\cancel{-}\frac{15v_1^2}{2g} = \cancel{-}2.7$$

$$\sqrt{v_1^2} = \sqrt{\frac{2.7 \times g(9.81)}{15}}$$

$$\boxed{v_1 = 1.879 \text{ m/sec}}$$

Putting the value of "v_1" in eq ②,

=> $v_2 = 4v_1$

$= 4(1.879)$

$$\boxed{v_2 = 7.516 \text{ m/sec}}$$

Also,

=> $Q_1 = A_1v_1$

$= by_1 \cdot v_1 = 3.9 \times 3.6 \times 1.879$

$$\boxed{Q_1 = 26.38 \text{ m}^3\text{/sec}}$$

=> $Q_2 = A_2v_2$

$= by_2 \cdot v_2 = 3.9 \times 0.9 \times 7.516$

$$\boxed{Q_2 = 26.38 \text{ m/sec}}$$

=> $Q = Q_1 = Q_2 = 26.38 \text{ m/sec}$.

Now:-

Froud Number At Upstream Side :-

By formula,

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{1.879}{\sqrt{9.81 \times 3.6}}$$

$$\boxed{Fr_1 = 0.31}$$

As $Fr_1 < 1$

$0.31 < 1 \rightarrow$ It is Sub-critical Flow.

Froud Number At Downstream Side:-

$$Fr_2 = \frac{V_2}{\sqrt{gy_2}} = \frac{7.516}{\sqrt{9.81 \times 0.9}}$$

$$\boxed{Fr_2 = 2.52}$$

As $Fr_2 > 1$

$2.52 > 1 \rightarrow$ It is Super-critical Flow.

END !!!

Section 2.2

Example.
A 3-m wide channel carries a total discharge of 12 $m^3 s^{-1}$. Calcul
(a) the critical depth;
(b) the minimum specific energy;
(c) the alternate depths when $E = 4$ m.

$b = 3$ m
$Q = 12 \text{ m}^3 \text{ s}^{-1}$

(a)
Discharge per unit width:

$$q = \frac{Q}{b} = \frac{12}{3} = 4 \text{ m}^2 \text{ s}^{-1}$$

Then, for a rectangular channel:

$$h_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{4^2}{9.81}\right)^{1/3} = 1.177 \text{ m}$$

Answer: critical depth = 1.18 m.

(b) For a rectangular channel,

$$E_c = \frac{3}{2} h_c = \frac{3}{2} \times 1.177 = 1.766 \text{ m}$$

Answer: minimum specific energy = 1.77 m

Answer: minimum specific energy = 1.77 m.

(c) As $E > E_c$, there are two possible depths for a given specific energy.

$$E \equiv h + \frac{V^2}{2g} \qquad \text{where} \qquad V = \frac{Q}{A} = \frac{q}{h} \qquad \text{(for a rectangular channel)}$$

$$\Rightarrow \qquad E \equiv h + \frac{q^2}{2gh^2}$$

Substituting values in metre-second units:

$$4 \equiv h + \frac{0.8155}{h^2}$$

For the *subcritical* (slow, deep) solution, the first term, associated with potential energy, dominates, so rearrange as:

$$h = 4 - \frac{0.8155}{h^2}$$

Iteration (from e.g. $h = 4$) gives $h = 3.9$[illegible] m

Problem 4.36

Water flows with a velocity of 2 m/s and at a depth of 3 m in a rectangular channel. What is the change in depth and in water surface elevation produced by a gradual upward change in bottom elevation (upstep) of 60 cm? What would be the depth and elevation changes if there were a gradual downstep of 15 cm? What is the maximum size of upstep that could exist before upstream depth changes would result? Neglect head losses.

Solution:

$$E_1 = y_1 + \frac{V_1^2}{2g} = 3\text{ m} + \frac{(2\text{ m/s})^2}{2 \cdot 9.81\text{ m/s}^2} = 3.20\text{ m}.$$

$$E_2 = E_1 - \Delta z = 3.20\text{ m} - 0.60\text{ m} = 2.60\text{ m}.$$

Also

$$E_2 = y_2 + \frac{q^2}{2gy_2^2} = y_2 + \frac{(6\text{ m}^3/\text{s/m})^2}{2 \cdot 9.81\text{ m/s}^2 \cdot y_2^2} = 2.60\text{ m}$$

so $y_2 = 2.24$ m. $\Delta y = y_2 - y_1 = -0.76$ m so water surface drops 0.16 m.

For a downward step of 15 cm we have

$$E_2 = E_1 - \Delta z = 3.20\text{ m} - (-0.15\text{ m}) = 3.35\text{ m}.$$

giving $y_2 = 3.17$ m and $\Delta y = y_2 - y_1 = 0.17$ m so water surface rises 0.02 m.

The maximum upstep possible before affecting upstream water surface le[illegible] is for $y_2 = y_c$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{(6\text{ m}^3/\text{s/m})^2}{9.81\text{ m/s}^2}} = 1.54\text{ m}.$$

Problem 4.39

Problem 4.22

Water flows at a depth of 10 cm with a velocity of 6 m/s in a rectangular channel. Is the flow subcritical or supercritical? What is the alternate depth?

Solution:

Check Froude number

$$Fr = \frac{V}{\sqrt{gy}} = \frac{6\ \text{m/s}}{\sqrt{9.81\ /\text{s}^2 \cdot 0.1\ \text{m}}} = 6.06 > 1$$

so the flow is supercritical.

$$E = y + \frac{V^2}{2g} = 0.1\ \text{m} + \frac{(6\ \text{m/s})^2}{2 \cdot 9.81\ \text{m/s}^2} = 1.935\ \text{m}$$

Solving for the alternate depth for an $E = 1.935$ m yields $y_{alt} = 1.93$ m

Problem 4.31

Derive a formula for critical depth, d_c in the V-shaped channel shown below.