আনিকা ইউনূস ম্যাডাম

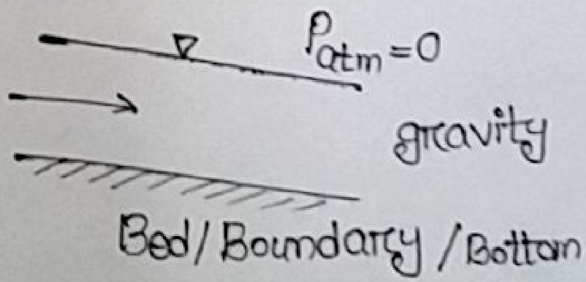
Lecture-1

Topics:

- M Open channel flow and its classification
- M Velocity and pressure distribution
- M Energy equation, specific energy and Transition problems.
- M Critical flow and control
- Concept of Uniform flow
- Chezy and Manning equation, estimation of resistance co-efficient and computation of uniform flow.
- Momentum equation and specific momentum
- M Hydraulic Jump
- Theory and analysis of gradually varied flow
- Computation of flow profile
- M Design of Channel

* 4th week C.T.

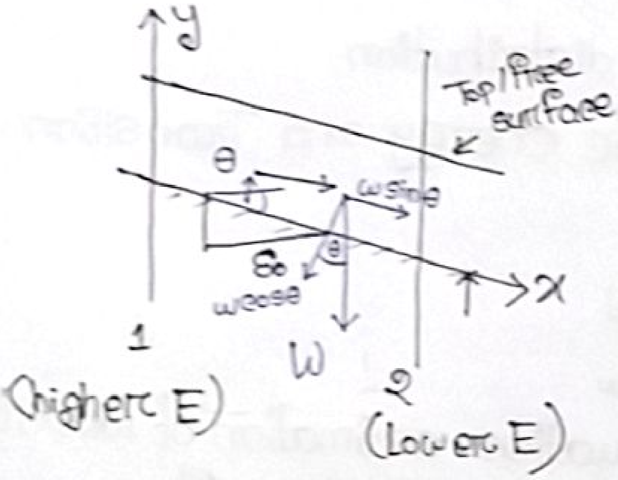
Open Channel Flow and its classification:



Lecture-2

Open Channel and its classification:

- free surface subjected to atmospheric pressure



- Direction of flow = Longitudinal direction
- s = side slope
- S_0 = Bed slope / Longitudinal slope
- $W\sin\theta$ = Driving force (এক section থেকে অন্য section এ water যায়)

Nature of Open channel Flow:

- SI unit use করব।

Kinds of open Channel:

(1) Natural and artificial:

(2) Prismatic and non-prismatic channel:

Prismatic: Cross section vary করেনা। (Artificial)

non-prismatic: cross section vary করে (All natural channels are non prismatic)

(3) Rigid and mobile boundary channel:

$\underbrace{\text{Rigid}}_{\text{bed slope constant}}$; $\underbrace{\text{mobile}}_{\text{bed slope different হলে}}$

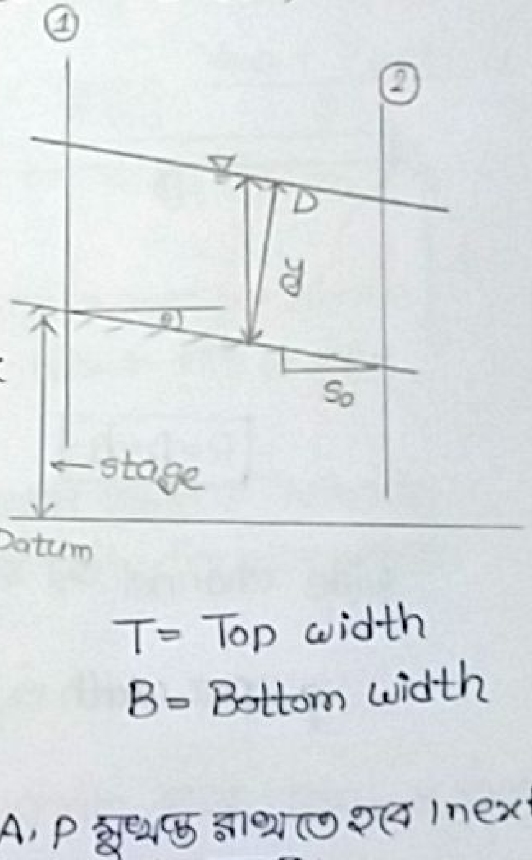
(4) Small and Large slope channel:

$\underbrace{1V : 10H}_{\text{এটা বড় হলে}}$ → Large

এটা বড় হলে → small

Channel Geometry and section elements:

- Depth of flow (y): Vertical direction এ (Y axis) depth.



prismatic channel এর X-section:
circular, rectangle, parabolic, triangular, trapezoidal.

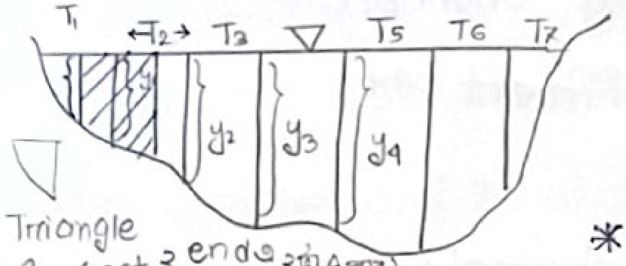
- Depth of flow section:
  flow এর direction এর perpendicular depth
- Stage:
  Datum থেকে bottom এর একটি point এ height

T = Top width
B = Bottom width

- Flow area: (A)
- Channel section:

* বিভিন্ন Type এর cross-section এর A, P মুখস্ত রাখতে হবে। next class এ ask করবে।

- Vertical channel section
- Wetted perimeter: (P)
- Top width
- Hydraulic radius (R)
- Hydraulic depth $(D) = \frac{A}{T}$



Triangle ধরে (last 2 end এ 2টা Δ পাব)

river section
(non-prismatic)

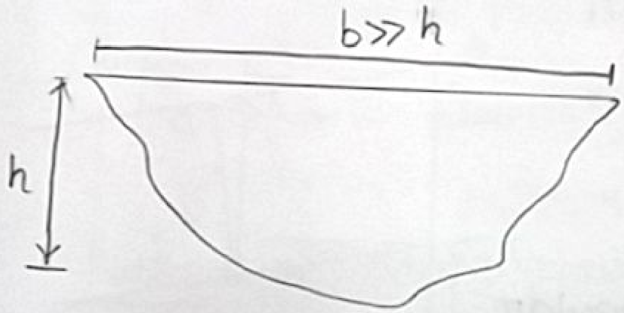
$$A = \frac{1}{2}(T_1 + T_2)\,y_1$$

* Trapezoidal rule apply করে area বের করব।

* Perimeter বের করার সময় bottom line গুলোকে straight line বিবেচনা করব।

□ Wide channel: means wide rectangular channel.

$b \gg h$.



$$\boxed{R = D = h}$$

$$R = \frac{A}{P} = \frac{bh}{b+2h} = \frac{bh}{b} = h$$

$$D = \frac{A}{T} = \frac{bh}{b} = h$$

For wide rectangular channel

'q' দিয়ে প্রকাশ করা হয়।

wide channel এর জন্য, $Q = m^3/s/m$
$= m^2/s$

q = per width এ discharge $= \frac{Q}{b}$ [unit m^2/s]

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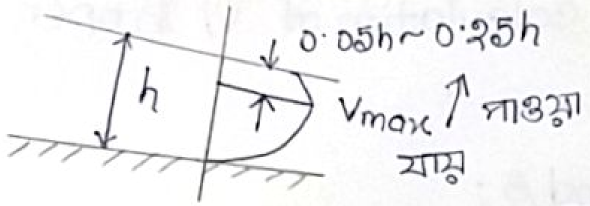
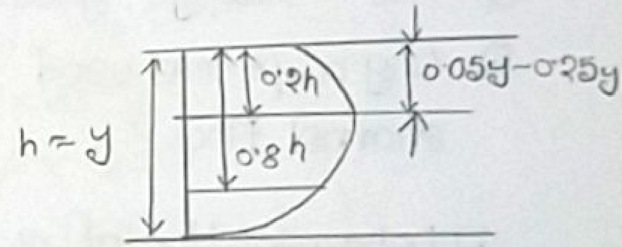
Lecture-3

Velocity and Pressure distribution

□ Velocity distribution :





যখন,

- $h \geq 0.61m$, $V_{avg} = \frac{V_{0.2h} + V_{0.8h}}{2}$
- $h < 0.61m$ হলে, $V_{avg} = V_{0.6h}$

- presence of free surface
- bottom এ friction

} এই দুটো কারণে parabolic distribution পাওয়া যায়

- unusual shape of channel
- The roughess of channel
- The presence of the bend

} এসব কারণেও velocity distribution vary করে।

□ Velocity distribution co-efficients :

Ⓐ * যদি ক্ষুদ্র ক্ষুদ্র area এর velocity integrate করে total v (actual) বের করি, তবে V_{avg} এর সাথে v এর একটা difference লক্ষ করা যায়।
তাই co-efficient α, β use করা হয় for V_{avg}.

correction factor

$$\left.\begin{cases} \alpha = \text{Kinetic energy co-efficient} \\ \beta = \text{Momentum calculation এর coefficient} \end{cases}\right\} \text{both are} > 1.$$

* α, β use করা হয় যদি V_{avg} use করি।

Q. ∴ α is always greater than β.

Q. Why α, β are used in calculation of v, in open channel flow?

☐ Determination of α and β :

$$\Delta Q = \Delta A \times v = \frac{Vol^m}{t}$$

$v \rightarrow$ velocity
$m \rightarrow$ mass $= \rho \times vol^m$
$e \rightarrow$

$$\frac{K.E}{t} = \frac{1}{2} m v^2 / t$$
$$= \left(\frac{1}{2} \rho \times Vol^m \times v^2\right) / t$$

incompressible fluid

$$= \frac{1}{2} \frac{\gamma}{g} \times \frac{Vol^m}{t} \times v^2$$
$$= \frac{1}{2} \frac{\gamma}{g} Q v^2$$
$$= \frac{\gamma}{2g} (\Delta A \times v) \times v^2$$
$$= \frac{\gamma}{2g} \Delta A \times v^3$$

Total K.E. per unit time $= \frac{\gamma}{2g} \int v^3 \, \Delta A$

Using avg. velocity , $\frac{K.E}{t} = \frac{\gamma}{2g} \bar{V}^3 A$

($\bar{V}$ = avg. velocity)

$\therefore \alpha \frac{\gamma}{2g} \bar{V}^3 A = \frac{\gamma}{2g} \int v^3 \, dA$

$$\therefore \boxed{\alpha = \frac{\int v^3 \, dA}{\bar{V}^3 A}}$$

□ β:

momentum per unit time $= (mv)/t$

$= (\rho \times vol^m \times v)/t$

$= \rho \times Q \times v$

$= \rho . (\Delta A \cdot v) \times v$

$= \rho \cdot \Delta A \cdot v^2$

T.M.

$\cancel{V} \cdot \cancel{t} = \rho \int v^2 \, dA$

Again, $M = \rho (\bar{V})^2 A$

$$\boxed{\therefore \beta = \frac{\int v^2 \, dA}{(\bar{V})^2 A}}$$

(Math) In a wide river, the velocity varies along a vertical. eqn $U = \left(1 + 2\frac{z}{y}\right)$ where, $y =$ ~~total~~ depth of water
U = velocity at a distance z from the channel bottom.

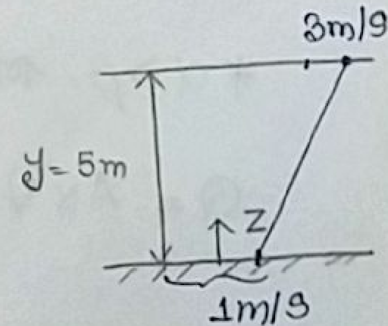
The $y = 5m$,

1) Determine the discharge per unit width

2) " α, β.

$U = 1 + \frac{2z}{y}$

$$\alpha = \frac{\int_0^A v^3 \, dA}{\bar{V}^3 A} = \frac{\int_0^y u^3 \, \cancel{dy} dz}{(\bar{V})^3 \times y}$$



$dA = b \times dy$

wide river, $b = 1m$

$\bar{V} = \frac{1+3}{2} = 2 \, m/s$

or, $\bar{V} = \frac{\int u \, dz}{y} = \frac{\int_0^y \left(1+\frac{2z}{y}\right) dz}{y} = \frac{y + \frac{2}{y} \times \frac{y^2}{2}}{y}$

$= 2$

Now, $\int_0^y u^3 dz$

$= \int_0^y \left(1+\frac{2z}{y}\right)^3 dz$

$= \int_0^y \left(1 + 3 \cdot \frac{2z}{y} + 3 \cdot \frac{4z^2}{y^2} + \frac{8z^3}{y^3}\right) dz$

$= \left[z + \frac{6}{y} \cdot \frac{z^2}{2} + \frac{12}{y^2} \frac{z^3}{3} + \frac{8}{y^3} \frac{z^4}{4}\right]_0^y$

$= y + 3y + 4y + 2y$

$= 10y$

$= 10 \times 5$

$= 50$

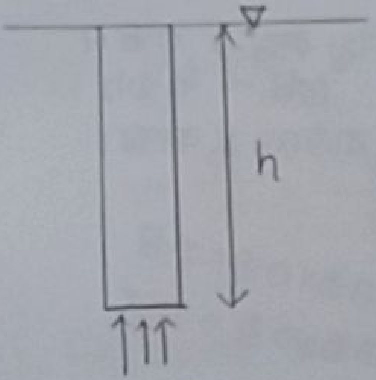
$\therefore \alpha = \frac{50}{(2)^3 \times 5} = \frac{10}{8} = \boxed{1.25}$

$\beta = \frac{\int v^2 dz}{(\bar{V})^2 y} = \frac{\int_0^5 \left(1+\frac{2z}{5}\right)^2 dz}{(2)^2 \times 5} = \frac{65/3}{4 \times 5} = \boxed{1.083}$

* $\alpha > \beta$, কারণ, α তে $\bar{V}^3$ আর β তে $\bar{V}^2$. তাই $\alpha > \beta$.

$Q = A \times \bar{V} = y \times \bar{V} = 5 \times 2 = \boxed{10 \, m^3/s \text{ per m.}}$

pressure distribution:

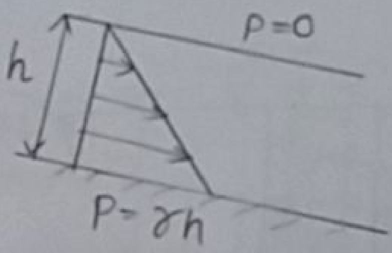


$p = \gamma h$ (Hydrostatic Law of P.)

Validity of Hydrostatic Law:

1) In open channel
2) all the stream lines are parallel
3) Uniform flow

not applicable in curvilinear, non-linear flow.



Lecture-4

বুধবার → স্যার
মঙ্গলবার → ম্যাডাম

মঙ্গলবার → স্যার
বুধবার → ম্যাডাম

* velocity কম → 0.8h
বেশি → 0.2h
∴ Depth বাড়লে V কমে।

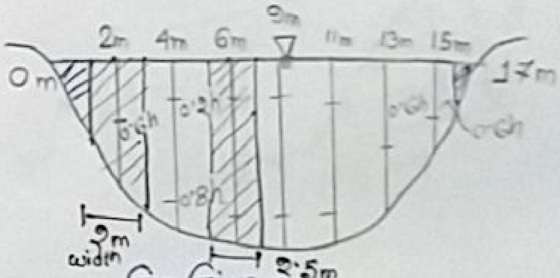
* $3.5 \times 0.8 = 2.8$
$3.5 \times 0.2 = 0.7$

Chapter-1:

□ Non prismatic channel:

(Math) $V = aN + b$

N = No. of revolution of current meter per unit time
a, b = constant of current meter
V = velocity



G = Given,

Distance from left bank (m) (G)	Total depth (m) (G)	Meter Depth (m)	Velocity (m/s) (G)	Width (m)	Area	velocity (m/s)	Q = AV
0	0		0				
2	1	0.6	0.54 = (0.6h)	2	2	0.54	2×0.54 = 1.08
4	3.5	2.8 (0.8h) / 0.7 (0.2h)	0.98 / 1.62	2	7	1.3	9.1
6	5.2	4.16 (0.8h) / 1.04 (0.2h)	1.35 / 1.6	2.5	13	(1.35+1.6)÷2 = 1.475	19.2
9	6.3	5.04 / 1.26	1.36 / 1.81	2.5	6.3×2.5 = 15.75	1.585	24.96
11	4.4	3.52 / 0.88	1.51 / 1.72	2	4.4×2 = 8.8	1.62	14.26
13	2.2	= 1.32	= 1.16	2	2.2×2 = 4.4	= 1.16	5.1
15	0.8	0.48	0.64	2	0.8×2 = 1.6	0.64	1.02
17	0				Σ = 52.55		

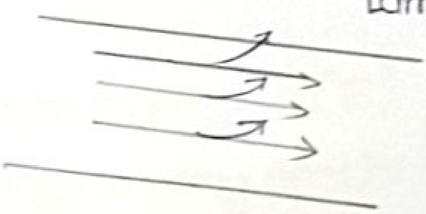
$\therefore A = 52.55\ m^2$ (২ side এর ২টা triangle add না করলেও চলবে) যদি করি, তবে depth ধরব আগের strip এর depth এর অর্ধেক)

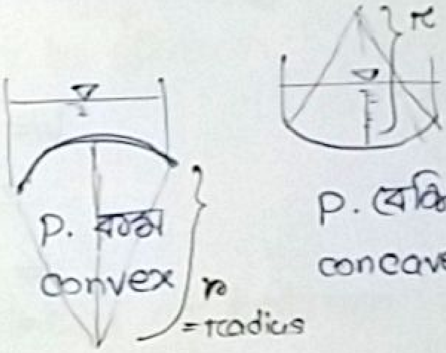
$Q = 74.76$

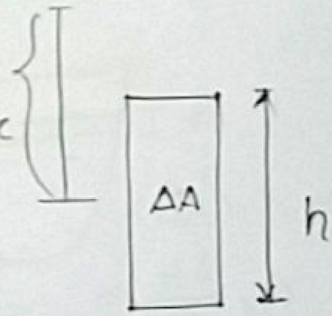
$\therefore V = \frac{Q}{A} = \frac{74.76}{52.55} = \boxed{1.42\ m/s}$ non-prismatic section এর velocity.

Imp □ Pressure distribution:

Laminar না হলে







$P_h = \gamma h$

$m = \rho Vol^m$

$= \rho(\Delta A \cdot h)$

$F_c = ma$

$= \rho(\Delta A \cdot h) \times \frac{v^2}{r}$

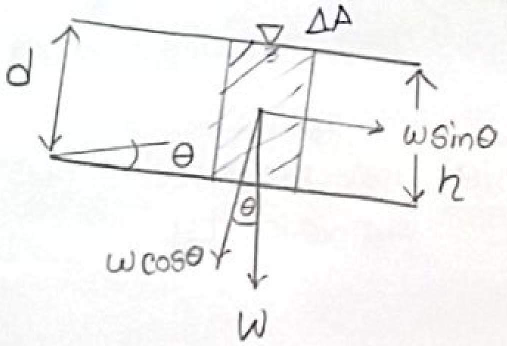
$P_c = \rho h \frac{v^2}{r} = (F_c / \Delta A)$

Total Pressure for concave $= \gamma h + \frac{\gamma}{g} h \frac{v^2}{r}$

convex $= \gamma h - \frac{\gamma}{g} h \frac{v^2}{r}$

Q. Curvilinear Flow এর জন্য Total P. কত ?

Effect of slope on pressure distribution:



$$P = \frac{F}{A} = \frac{w\cos\theta}{\Delta A}$$

$$= \frac{\gamma \Delta A\, d\cos\theta}{\Delta A}$$

$$= \gamma d\cos\theta$$

$$= \gamma (h\cos\theta)\cos\theta$$

$$= \gamma h\cos^2\theta$$

$$W = mg$$

$$= \rho\, \text{vol}^m g$$

$$= \gamma \cdot \text{vol}^m$$

$$= \gamma(\Delta A \cdot d)$$

Lecture-5

Chapter-3

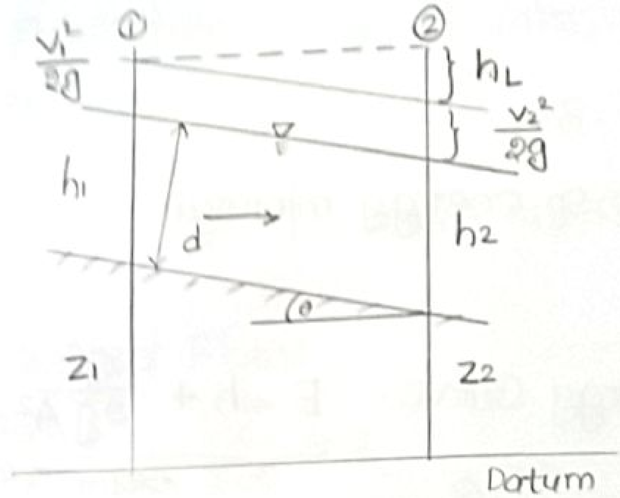
WRE - anika madam
V.T. Chow - বই এর
Chapter- 1, 2, 3, 7

Specific Energy & Transition Problems

3 Governing eq^n in OCF:

1) Continuity eq^n
2) Energy eq^n
3) Momentum eq^n

2) Energy eq^n for OCF : (Bernouli)



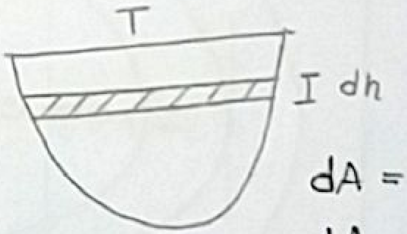
$$\underbrace{z_1+h_1+\frac{V_1^2}{2g}}_{\text{Total energy}} = \underbrace{z_2+h_2+\frac{V_2^2}{2g}+h_L}_{T\cdot E}$$

T·E = energy at any section w.r.to. Datum.

Specific Energy : (E)

Energy at any section w.r. to channel bed or bottom

$$\therefore \boxed{\text{Total}\cdot E = S.E + Z}$$



$dA = T\cdot dh$

$\Rightarrow \frac{dA}{dh} = T$

$\frac{Q}{A} = u$

$h = d\cos\theta$

$$E = h + \frac{v^2}{2g}$$

$$= h + \frac{Q^2}{2gA^2} = h + \frac{Q^2}{2gA^2}$$

$$E = f(h)$$

$$\therefore \frac{dE}{dh} = \frac{dh}{dh} + \frac{Q^2}{2g}\frac{d}{dh}(A^{-2})$$

$$= 1 - 2\frac{Q^2}{2g}A^{-3}\frac{dA}{dh}$$

$$= 1 - \frac{Q^2}{gA^3}\cdot T$$

$$= 1 - \frac{Q^2 T}{gA^3}$$

$$\therefore \frac{dE}{dh} = 1 - \frac{u^2}{g\frac{A}{T}} = 1 - \frac{u^2}{gD} = 1 - (F_r)^2$$

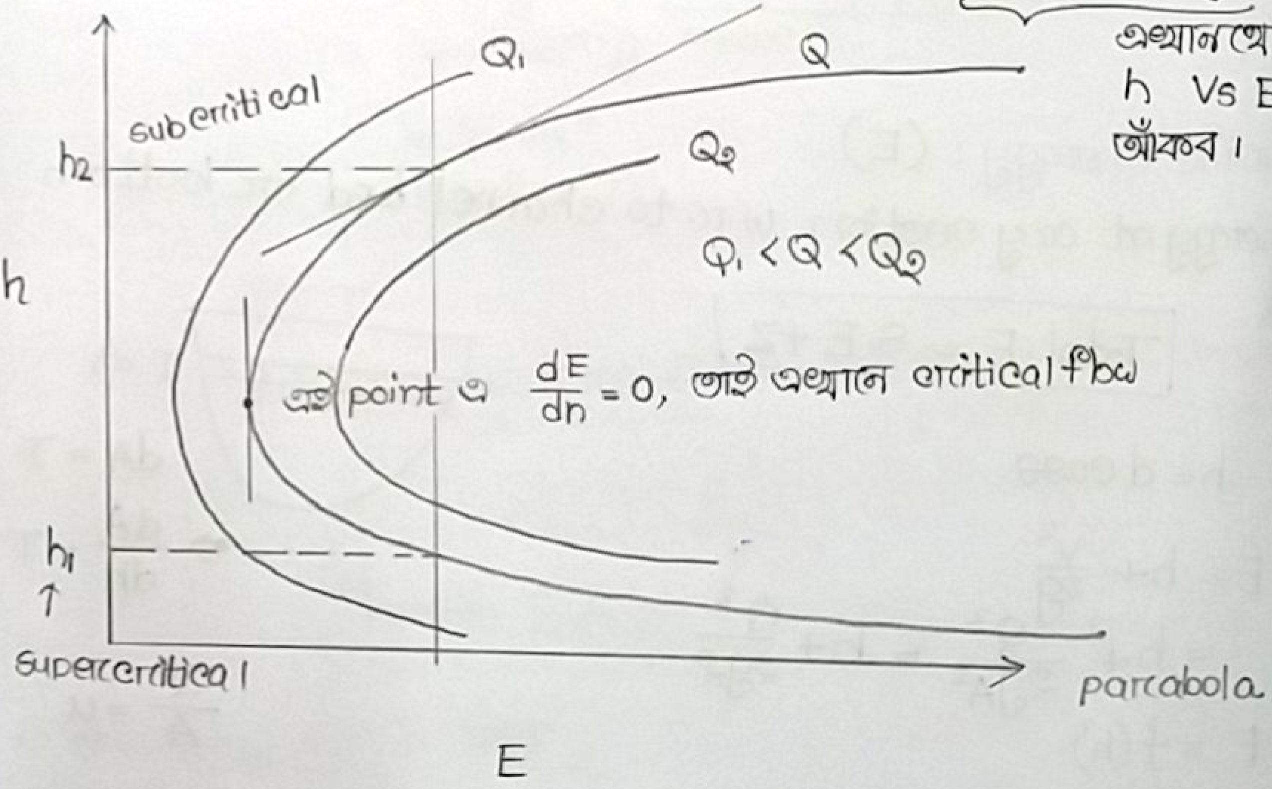
For max or min,

$$\frac{dE}{dh} = 0$$

$\therefore 0 = 1 - Fr^2$

Imp Q. $\therefore Fr = 1$ (Flow critical), sp. energy minimum and slope, $\theta = 0$

v. Imp Q. Describe Specific Energy Curve. $E = \underbrace{h + \frac{Q^2}{2gA^2}}$ এখান থেকে h Vs E curve আঁকব।



- If $h \to 0, E \to \infty$; $h \to \infty, E \to \infty$ } তাই ~~hyperbola~~ parabola
- যে কোন specific E. এর জন্য h এর ২টি value পাওয়া যায়। শুধুমাত্র যে point এ critical flow হয়, সেখানে h এর ১টি value পাওয়া যায়।
- যে point এ slope 0, সেখানে critical. অন্য সব point এই slope পাওয়া যায়।

- h এর ২টি value indicate করে ২টি flow condition.

subcritical — h_2, (h বেশি, তাই V কম, তাই subcritical)

supercritical — h_1 (h কম, V বেশি, তাই supercritical)

- $Q \uparrow$, $E \uparrow$, তাই Q_2 ডানে, Q_1 বামে।

□ Critical Flow:

$Fr_c = 1$, $\frac{u_c^2}{gD_c} = 1$

$\Rightarrow \frac{u_c^2}{2g} = \frac{D_c}{2}$

$E_c = h_c + \frac{u_c^2}{2g}$

For rectangular channel, $h_c = D_c$

$\therefore E_c = h_c + \frac{D_c}{2}$

$= h_c + \frac{h_c}{2}$

$\boxed{E_c = \frac{3}{2} h_c}$ Exam এ আসে

** Trapezium, triangle এই shape এর জন্য E_c কষ্ট করে বের করতে হবে।

□ Section factor: (Z)

$Z = A\sqrt{D}$

rectangular cross section বাদে অন্য X-section এর জন্য h_c আর্টা বের করার সময় এটা লাগবে।

☐ Computation of Critical Depth:

1) Wide
2) rectangular
3) triangular
4) parabolic

} channel., using direct method

5) trapezoidal
6) circular

} using trial-error

Computation of Critical Depth: (Imp Exam)

1) Wide
2) rectangular
3) triangular
4) parabolic

} channel, using direct method or analytical method

5) trapezoidal
6) circular

} using trial-error

Lecture-6

{C.T → Chapter-1 22/3/17

- critical stage ↪,

** $\boxed{\dfrac{V_c^2}{2g} = \dfrac{1}{2} d_c}$

$$\frac{u_c^2}{2g} = \frac{D_c}{2}$$

$$\Rightarrow \frac{Q^2}{2g A_c^2} = \frac{D_c}{2}$$

$$\Rightarrow \boxed{A_c \sqrt{D_c} = \frac{Q}{\sqrt{g/\alpha}}} = Z$$

◻ Wide channel: $\boxed{h_c = \left(\dfrac{q^2}{g}\right)^{\frac{1}{3}}}$

q = Discharge per unit width

$\therefore Q = bq$

$$\frac{u_c^2}{2g} = \frac{D_c}{2} = \frac{h_c}{2}$$ [for wide rectangle, $D_c = h_c$]

$$\Rightarrow \frac{q^2}{2g(A_c)^2} = \frac{h_c}{2}$$

$$\Rightarrow \frac{q^2}{g\,(b\times h_c)^2} = \frac{h_c}{\cancel{2}}$$

$$\Rightarrow \frac{q^2}{g\,h_c^2} = \frac{h_c}{1} \quad [b=1]$$

$$\Rightarrow q^2 = g\,h_c^3$$

$$\therefore \boxed{h_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}}$$

□ Rectangular:

$$\frac{u_c^2}{2g} = \frac{h_c}{2}$$

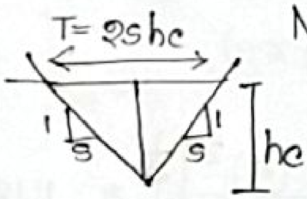
$$\Rightarrow \frac{(Q/A)^2}{2g} = \frac{h_c}{2}$$

$$\Rightarrow \frac{Q^2}{2g\,A^2} = \frac{h_c}{2}$$

$$\Rightarrow \frac{Q^2}{2g\times b^2\times h_c^2} = \frac{h_c}{2}$$

$$\Rightarrow \frac{Q^2}{g b^2} = h_c^3$$

$$\therefore \cancel{h_c}\ \boxed{h_c = \left(\frac{Q^2}{g b^2}\right)^{\frac{1}{3}}}$$



$A = s h_c^2$

□ Triangular:

$$\frac{u^2}{2g} = \frac{\cancel{h_c}}{\cancel{2}}\ \frac{D_c}{2}$$

$$\Rightarrow \frac{Q^2}{2g\times A^2} = \frac{\cancel{h_c}}{\cancel{2}}\ \frac{D_c}{2}$$

$$\Rightarrow \frac{\cancel{2b^2}\,Q^2}{g\times A^2} = D_c$$

Now, $D_c = \dfrac{A}{\text{Top width}}$

$$= \frac{\frac{1}{2}\times 2s\times h_c\times h_c}{2s\,h_c}$$

$$= \frac{\cancel{s}\,h_c}{2}$$

$$\therefore \frac{u^2}{2g} = \frac{D_c}{2} = \frac{h_c/2}{2}$$

$$\Rightarrow \frac{u^2}{2g} = \frac{h_c}{4}$$

$$\Rightarrow \frac{Q^2}{2g\,A^2} = \frac{h_c}{4}$$

$$\Rightarrow \frac{Q^2}{2g\times s h_c^2} = \frac{h_c}{4}$$

$$\Rightarrow \frac{Q^2}{g s} = \frac{h_c^3}{2}$$

$$\therefore \boxed{h_c = \left(\frac{Q^2}{2gs}\right)^{\frac{1}{3}}} \times$$

$$h_c = \left(\frac{2Q^2}{g s^2}\right)^{\frac{1}{5}}$$

Problem 1

compute critical depth, for

(a) wide rectangular channel with $q = 4\ m^2/s$

(b) rectangular channel with $b = 6m$, $Q = 35\ m^3/s$

(c) triangular channel with $s = 1$ and $Q = 5m^3/s$

(d) parabolic, $y^2 = 5z$, $Q = 25m^3/s$.

$\alpha = 1.12$ (for all cases).

α add করতে হবে। So, এগুলো ans না

(a) $h_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}} = \left\{\frac{(4)^2}{9.81}\right\}^{\frac{1}{3}} = 1.18\ m$

(b) $h_c = \left(\frac{Q^2}{gb^2}\right)^{\frac{1}{3}} = \left\{\frac{(35)^2}{9.81 \times 6^2}\right\}^{\frac{1}{3}} = 1.51\ m$

(c) $h_c = \left(\frac{Q^2}{2gs}\right)^{\frac{1}{3}} = \left\{\frac{(5)^2}{2 \times 9.81 \times 1}\right\}^{\frac{1}{3}} = 1.08\ m$

(d) $h_c = \sqrt[4]{\frac{27\alpha c Q^2}{32g}}$

$= \sqrt[4]{\frac{27 \times 1.12 \times \frac{1}{5} \times (25)^2}{32 \times 9.81}}$

$= 1.86\ m$

$z = cy^2$

$\Rightarrow c = \frac{z}{y^2} = \frac{y^2}{5 \times y^2} = \frac{1}{5}$

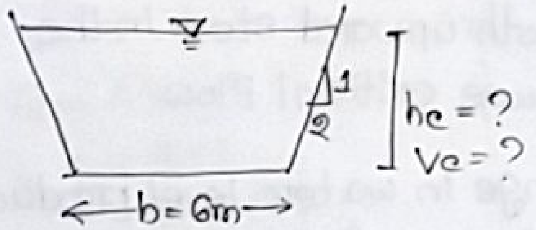
Problem 2

Compute critical depth and velocity in a

(1) trapezoidal channel with $b = 6m$, $S = 2$ and $Q = 35\ m^3/S$

(2) Circular channel with $d_o = 3m$ and $Q = 5\ m^3/S$. In all cases assume $\alpha = 1.12$.

(1)



$$A\sqrt{D} = \frac{Q}{\sqrt{g/\alpha}}$$

$$= \frac{35}{\sqrt{\frac{9.81}{1.12}}}$$

$$\therefore A\sqrt{D} = 11.83$$ (.01 or .02 difference থাকতে পারে)

$A = (b + Sh_c)h_c$

$T = b + 2Sh_c$

$D = \frac{A}{T}$

h_c (m)	A (m^2)	T (m)	D (m)	$A\sqrt{D}$	comment
1	8	10	0.8	7.15	hc is to increase
2.0	20	14	1.43	23.9	hc is to decrease
1.4	12.3	11.6	1.06	12.66	hc is to decrease
1.38	12.09	11.52	1.05	12.38	hc is to decrease
1.32	11.4	11.28	1.01	11.46	hc is to increase
$\boxed{1.35}$	11.75	11.4	1.03	11.93	$\therefore V_c = \frac{Q}{A} = \frac{35}{11.75} = \boxed{2.98\ m/S}$

Lecture-7

Channel with a change in bed level: (head loss নাই assume)

Problem (3)

Water flows at a velocity of 1m/s and a depth of 1.5m in a long rectangular channel 3m wide. Compute

(a) the height of a smooth upward step in the channel bed to produce critical flow

(b) the depth and the change in water level produced by

(1) a smooth upward step of 0.45m
(2) a smooth " " of 0.8m
(3) " " downward " " 0.45m

assuming that the discharge in the channel does not change. In all cases, neglect energy losses and take $\alpha = 1$.

Control:

এমন একটি structure যার H ও Q relationship জানা অর্থাৎ K, n value জানা আছে যার।

- subcritical flow is affected by downstream condition
- supercritical " " " , upstream "

□ Transition problem :

- Bed level উঠিয়ে বা নামিয়ে
- width change করে

} Transition

<u>solution of (3):</u>

$b = 3m$

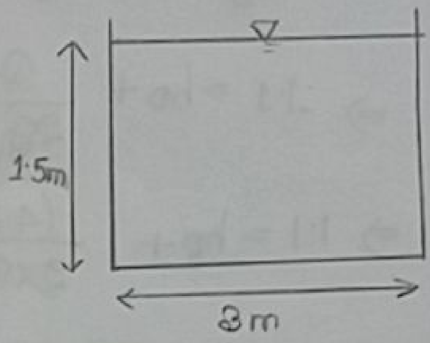
$h = 1.5m$

$v = 1 m/s$

$Q = Av$
$= 4.5 \times 1$
$= 4.5 m^3/s$

$A = b \times h$
$= 3 \times 1.5$
$= 4.5 m^2$

$D = \frac{A}{T} = \frac{A}{b} = \frac{4.5}{3}$
$= 1.5m$



(a) $E_1 = E_2 + \Delta Z$

E_1 = upstream energy head

E_2 = D.S "

$E_1 = h_1 + \frac{v_1^2}{2g}$
$= 1.5 + \frac{(1)^2}{2 \times 9.81}$
$= 1.55 m$

$E_2 \rightarrow$ critical or sp. energy
$= E_c$
$= \frac{3}{2} h_c$ [for rectangle channel]
$= \frac{3}{2} \left(\frac{Q^2}{gb^2}\right)^{\cancel{3/2}\ \frac{1}{3}}$
$= \frac{3}{2} \left[\frac{(4.5)^2}{9.81 \times (3)^2}\right]^{\cancel{3/2}\ \frac{1}{3}}$
$= \cancel{0.165}\ 0.92 m$

$\Delta Z = E_1 - E_2 = 1.55 - 0.92 = \boxed{0.63m}$

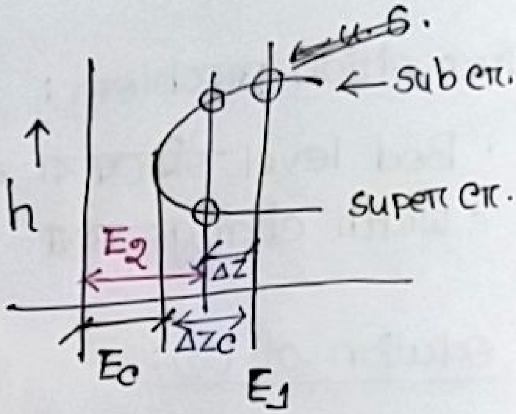
ΔZ = যতটুকু rise করতে হবে bed level

U.S condition, $F_r = \frac{u_1}{\sqrt{gD_1}}$
$= \frac{1}{\sqrt{9.81 \times 1.5}}$
$= 0.26 < 1$ (sub)

$h_c = \left(\frac{Q^2}{gb^2}\right)^{\frac{1}{3}}$
$= 0.61 m$

E_c = minimum sp. energy $= 0.92m$

(b)(1) $\Delta Z = 0.45m < \Delta Z_c$



$$E_1 = E_2 + \Delta Z$$

$$\Rightarrow 1.55 = E_2 + 0.45$$

$$\therefore E_2 = 1.1 = h_2 + \frac{u_2^2}{2g}$$

$$\Rightarrow 1.1 = h_2 + \frac{Q^2}{2g\, b^2 h_2^2}$$

$$\Rightarrow 1.1 = h_2 + \frac{(4.5)^2}{2\times 9.81 \times (3)^2 \times h_2^2}$$

$$\Rightarrow 1.1 = h_2 + \frac{0.115}{h_2^2}$$

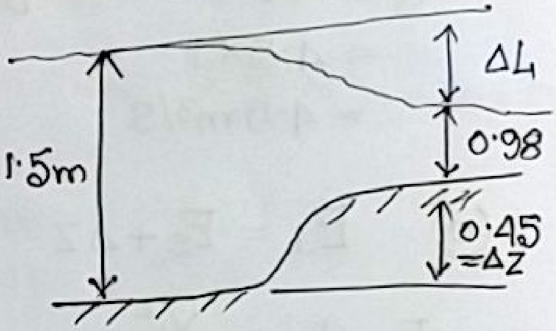
$$\Rightarrow 1.1\, h_2^2 = h_2^3 + 0.115$$

$$\Rightarrow h_2^3 - 1.1\, h_2^2 + 0.115 = 0$$

$$\therefore h_2 = -0.29, \; 0.98, \; 0.41$$

× ✓

U.S condition change হয় নি। তাই E_1 fixed থাকছে। E_2 change হল।



যেহেতু U.S condition exceed করে নি, তাই, 0.98 হবে h_2.
যেহেতু, $Fr<1$, তাই subcritical condition prevail করে বলে 0.98 নিচ্ছি।

Drop in water level = $1.5 - 0.98 - 0.45 = \boxed{0.07\,m = \Delta L}$

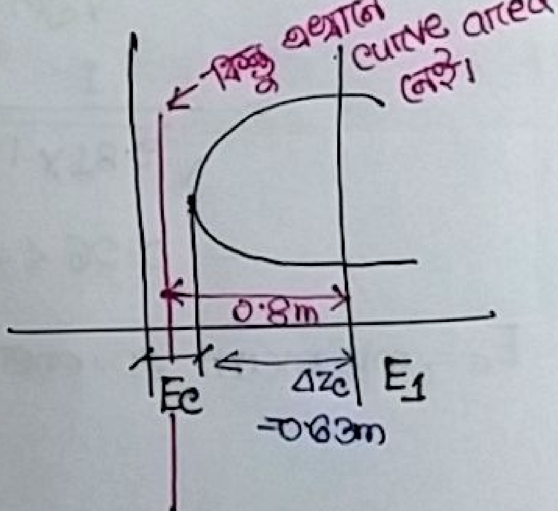
(2) $\Delta Z = 0.8m > \Delta Z_c$

$$E_c = 0.92m$$

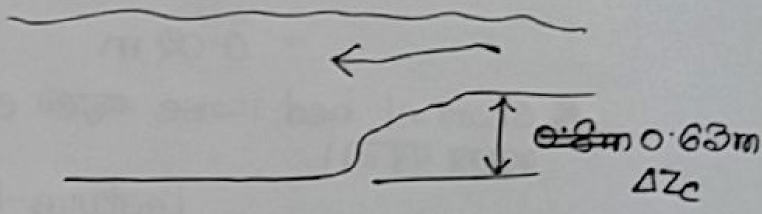
$$E_1 = E_c + \Delta Z$$

$$= 0.92 + 0.8$$

$$= 1.72m$$



তাই water তার minimum energy E_c বজায় রেখে Backward flow করবে।



$$\therefore E_1' = h_1' + \frac{v_1^2}{2g}$$

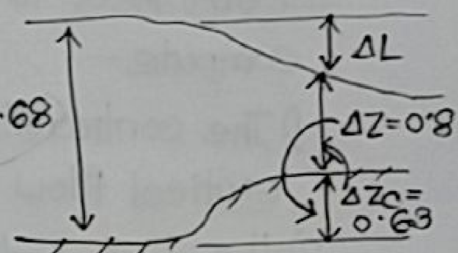
$$\Rightarrow 1.72 = h_1' + \frac{Q^2}{2gb^2 \, h_1'^2}$$

$$\Rightarrow 1.72 = h_1' + \frac{(4.5)^2}{2\times 9.81 \times (3)^2 \times h_1'^2}$$

$$\Rightarrow 1.72\, h_1'^2 = h_1'^3 + 0.115$$

$$\Rightarrow h_1'^3 - 1.72\, h_1'^2 + 0.115 = 0$$

$$\therefore h_1'^3 = 1.68\,m$$



Drop in water level $= 1.68 - 0.63 - 0.8$
$= 0.25m \ (\Delta L)$

(3) $E_1 = E_2 + \Delta Z$

$\Rightarrow 1.55 = E_2 - 0.45$ (downward, তাই (-ve))

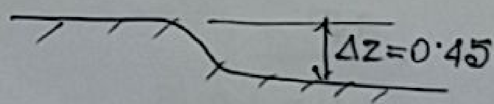
$$\Rightarrow E_2 = 2$$

$$\Rightarrow h_2 + \frac{v^2}{2g} = 2$$

$$\Rightarrow h_2 + \frac{Q^2}{2gb^2h_2^2} = 2$$

$$\Rightarrow h_2 + \frac{(4.5)^2}{2\times 9.81 \times 3^2 \times h_2^2} = 2$$

$$\Rightarrow h_2^3 + 0.115 = 2h_2^2$$



$$\therefore h_2 = 1.97m$$

$\therefore$ Rise in WL $= 1.97 - 1.5 - 0.45$

$= 0.02$ m

* channel bed raise করলে critical flow তৈরি হয়, lower করলে হয় না।

Lecture-8

Transition problem- change in width:

Problem

Water flows at a velocity of 1 m/s and a depth of 1.5m in a long rectangle channel of 3m wide.

Compute-

1) The contraction in width of the channel to produce critical flow

2) the depth and the change in water level produced by

   a) smooth contraction in width to 2 m

   b) smotth " " " to 1 m

   c) " expansion in width to 4m

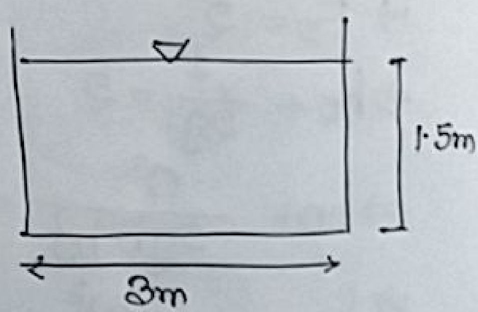
assuming that the discharge in the channel doesn't change. Here, $\alpha = 1$ in all cases.

Soln

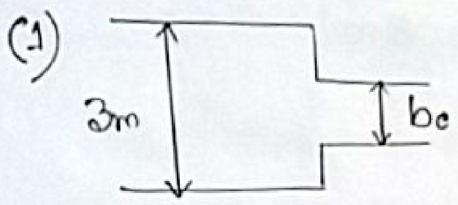
$v = 1$ m/s

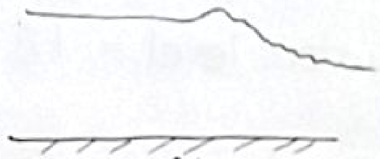
$A_1 = 4.5 m^2$

$Q = AU = 1 \times 4.5 = 4.5\ m^3/s$



(1)





$E_1 = E_c$

$\Rightarrow h_1 + \frac{U_1^2}{2g} = E_c$

$\Rightarrow 1.5 + \frac{(1)^2}{2 \times 9.81} = E_c$

$\Rightarrow 1.55 = E_c$

$\Rightarrow E_c = 1.55 = \frac{3}{2} h_c$ [for rectangle channel, $E_c = \frac{3}{2} h_c$]

$\therefore h_c = 1.03m$

U/S

$Fr_1 = \frac{U_1}{\sqrt{gD_1}}$

$= \frac{1}{\sqrt{9.81 \times \frac{4.5}{3}}}$

$= 0.26 < 1$

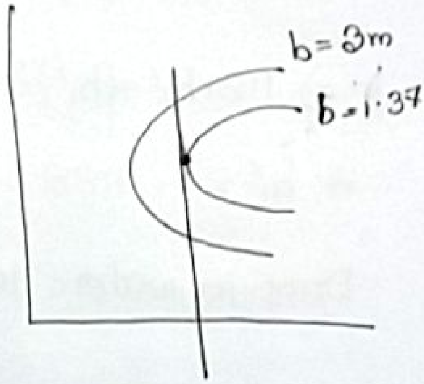
subcritical

$h_c = \left\{ \frac{Q^2}{g b_c^2} \right\}^{\frac{1}{3}}$

$\Rightarrow (1.03) = \left\{ \frac{(4.5)^2}{9.81 \times b_c^2} \right\}^{\frac{1}{3}}$

$\Rightarrow (1.03)^3 = \frac{(4.5)^2}{9.81 \times b_c^2}$

$\boxed{\therefore b_c = 1.37 \text{ m}}$



(2) (a) $b = 2m < 1.37m$ (So, critical condition এর আগে, অর্থাৎ U/S condition এ flow থাকবে)

$E_1 = E_2 = h_2 + \frac{V_2^2}{2g}$

$\Rightarrow 1.55 = h_2 + \frac{Q^2}{2 \times g\ b_2^2 \times h_2^2}$

$\Rightarrow 1.55 = h_2 + \frac{(4.5)^2}{2 \times 9.81 \times (2)^2 \times h_2^2}$

$\Rightarrow 1.55 h_2^2 = h_2^3 + 0.258$

$\therefore h_2 = 1.42m, 0.49$

h_2 = water level at downstream

$= 1.42m$

$\therefore$ drop in water level $= 1.5 - 1.42 = 0.08\,m$

(b) $b = 1m < b_c$

$E_1' = E_c = \frac{3}{2} h_c$ $\qquad\qquad h_c = 1.27\,m$

$= \frac{3}{2}\left\{\frac{Q^2}{g b^2}\right\}^{\frac{1}{3}}$

$= \frac{3}{2}\left\{\frac{(4.5)^2}{9.81 \times (1)^2}\right\}^{1/3}$

$= 1.91\,m$

$\therefore E_1' = h_1' + \frac{V_1^2}{2g}$

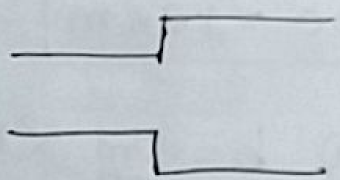
$\Rightarrow 1.91 = h_1' + \frac{(4.5)^2}{2 \times 9.81 \times (1)^2 \times h_1'}$

$\Rightarrow 1.91 h_1' = (h_1')^2 + 1.03$

$\Rightarrow h_1' = 1.88, 0.26$

Drop in water level $= 1.88 - 1.27 = 0.61\,m$

(c) $b = 4m$



$E_1 = E_2 = 1.55 = h_2 + \frac{V_2^2}{2g}$

$\Rightarrow 1.55 = h_2 + \frac{(4.5)^2}{2 \times 9.81 \times (4)^2 \times h_2^2}$

$\Rightarrow 1.55 h_2^2 = h_2^3 + 0.065$

$\therefore h_2 = 1.52, 0.22\,m$

Rise in water level $= 1.52 - 1.5 = 0.02\,m$

$\therefore$ expansion হলে critical condition হয় না।

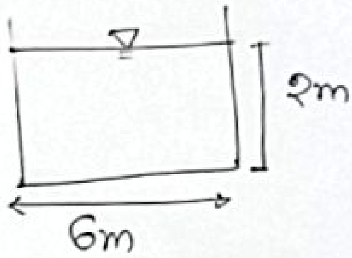
Scanned by CamScanner

Problem (Combined)

Water flows in a 6m wide rectangular channel at a depth of 2m and a velocity of 2m/s. The channel is contracted to a width of 3m. How much the channel bottom is to be simultaneously raised or lowered for the flow to be possible or critical.

Assume $\alpha = 1$.

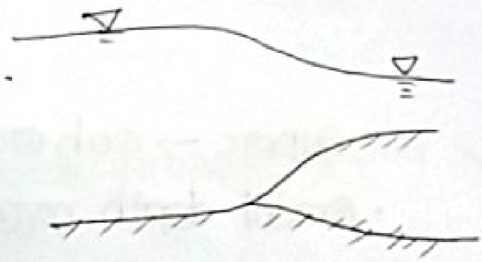
Solution



$V = 2\,m/s$

$A_1 = 2 \times 6 = 12\,m^2$

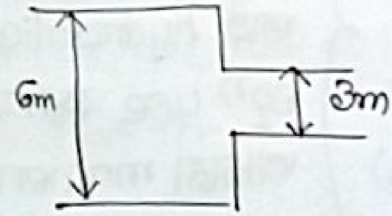
$Q = A_1 V = 2 \times 12 = 24\,m^3/s$



$E_1 = \cancel{E_2}$

$\Rightarrow h_1 + \frac{v_1^2}{2g} = \cancel{h_2} + \cancel{\frac{v_2^2}{2g}}$

$\Rightarrow 2 + \frac{Q^2}{h_1^2 b_1^2 \times 2g} = \cancel{h_2} + \cancel{\frac{Q^2}{h_2^2 b_2^2 \times 2g}}$



$\Rightarrow 2 + \frac{(24)^2}{(2)^2 \times (6)^2 \times 2 \times 9.81} = \cancel{h_2} + \cancel{\frac{(24)^2}{h_2^2 \times 3^2 \times 2g}}$

$\Rightarrow 2.204 = \cancel{h_2} + \cancel{\frac{3.26}{h_2^2}}$

$\Rightarrow \cancel{2.204 h_2^2 = h_2^3 + 3.26}$

$\therefore \cancel{h_2 = -1.00},$

$h_c = \left\{ \frac{Q^2}{g b_c^2} \right\}^{1/3}$

$= \left\{ \frac{(24)^2}{9.81 \times (3)^2} \right\}^{\frac{1}{3}}$

$= 1.87$

$E_c = \frac{3}{2} \times h_c = \frac{3}{2} \times 1.87 = 2.805\,m$

Channel bed

$E_1 = E_c + \Delta Z$

$\therefore \Delta Z = 2.204 - 2.805 = -0.6\,m$ (নামাবো)

Q.* Alternatively, b কত কম কমাতে or বাড়াতে হবে ?

$\boxed{\text{Next C.T} \rightarrow \text{specific energy}}$

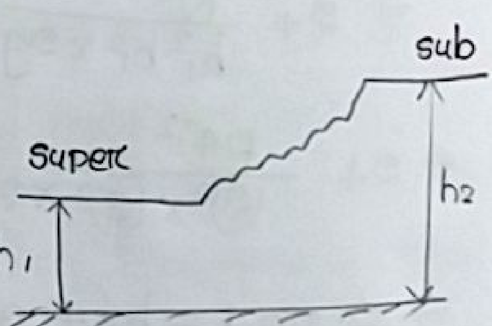
Lecture-9

Lecture-10

Hydraulic Jump

- Super → sub critical flow হওয়া
- small depth থেকে large depth হওয়া।

(A)
- প্রচুর energy dissipation হয়। তাই hydraulic jump এ energy eqn use করা যায় না। আমরা momentum eqn apply করব।



Q. hydraulic jump এ কেন energy eqn use করা যায় না ?

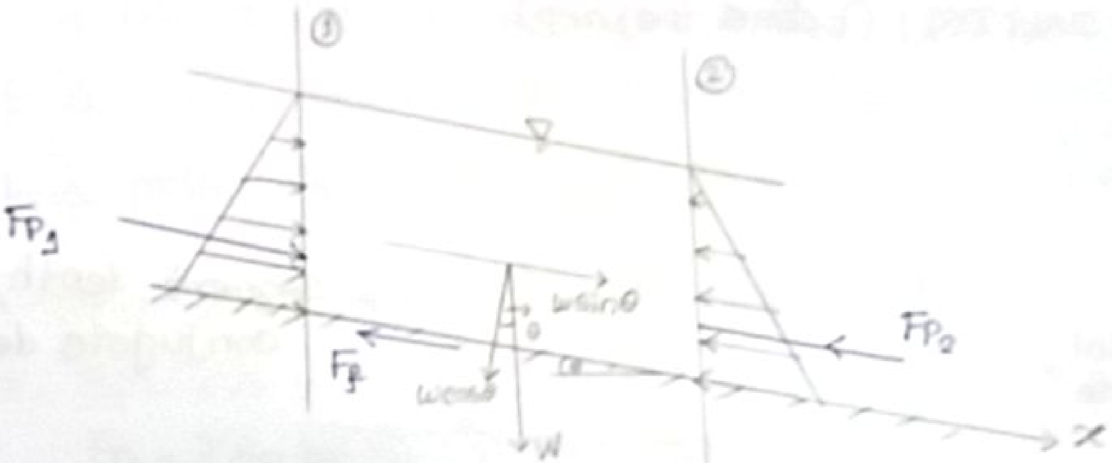
$\theta \approx 0$

horizontal বা mild slope channel

□ Momentum equation:

$$\Sigma F \propto m \frac{dv}{dt} \quad \frac{d(mv)}{dt}$$

Let us consider the control volᵐ bounded by section 1 and 2 as shown in the fig. The various forces acting on the control volᵐ in the longitudinal directions are:



1) The resultant hydrostatic pressure forces F_{P_1} and F_{P_2} at the two section end.

2) The forces due to gravity, $W\sin\theta$, which is the component of the weight of water in the longitudinal

3) The external friction force F_f acting on the opposite direction of flow.

$$F_{P_1} - F_{P_2} + W\sin\theta - F_f = (\beta_2 m V_2 - \beta_1 m V_1)$$
$$= \rho Q (\beta_2 V_2 - \beta_1 V_1)$$

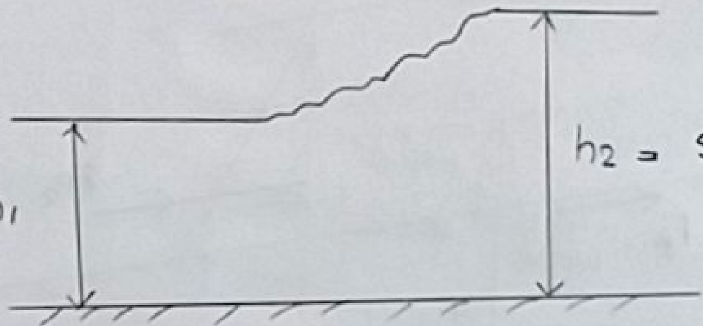
mv
$= \rho \, Vol^m \, v$
$= \rho Q v$

$$Q = \frac{d\,Vol^m}{dt}$$

This is the momentum eqn for 1D steady flow situation.

Strength of Hydraulic Jump:

U/S condition এর উপর depend করে (Fr no.) এর উপর depend করে hydraulic jump এর energy dissipation কেমন হবে। (before the jump)



initial depth $= h_1$

h_2 = sequent depth/ conjugate depth.

V বাড়ছে

1. $1 < Fr_1 < 1.7$ (Velocity কম) → Undular Jump
2. $1.7 < Fr_1 < 2.5$ (" একটু বেশি) → Weak Jump
3. $2.5 < Fr_1 < 4.5$ → oscillating Jump
4. $4.5 < Fr_1 < 9$ → steady Jump
5. $Fr_1 > 9$ → strong Jump
↑ (D/S water surface rough, energy dissipation বেশি)

<u>Sequent Depth</u> (Jump হবার পর Final depth)

From momentum eqⁿ,

$$\rho Q(\beta_2 V_2 - \beta_1 V_1) = F_{P_1} - F_{P_2} + W\sin\theta - F_f$$

We consider hydraulic jump occurring

Assumptions 'Q' আসে exam এ

(1) in a horizontal rectangular channel $(\theta = 0)$

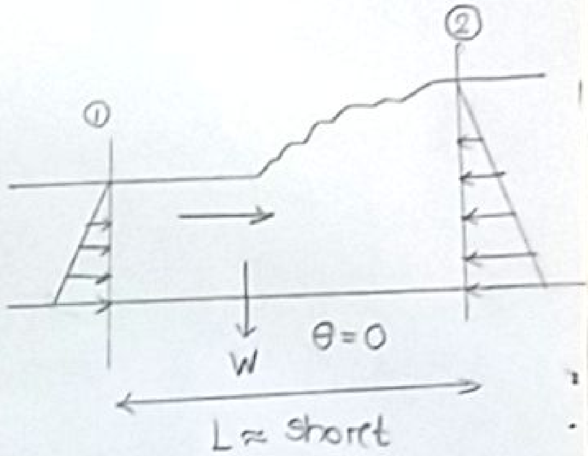
(2) in a short reach of the channel $(F_f = 0)$ [Length of ① and ② section is small]

(3) in a prismatic channel $(\beta_1 = \beta_2 = 1)$

So, Finally, $\rho Q(V_2 - V_1) = F_{P_1} - F_{P_2}$

Here, $F_{P_1} = \gamma A_1 \cancel{b_1} z_1$ | $V_1 = \dfrac{Q}{A_1}$

$F_{P_2} = \gamma A_2 \cancel{b_2} z_2$ | $V_2 = \dfrac{Q}{A_2}$



$z \rightarrow$ vertical distance of the centroid of the respective water area

(for rectangular area, $z = \frac{h}{2}$)

~~z = centroidal distance~~ $\cancel{= \frac{2}{3}h}$

width = b = common

$$\therefore \rho Q\left(\frac{Q}{A_2} - \frac{Q}{A_1}\right) = \gamma A_1 z_1 - \gamma A_2 z_2$$

$$\Rightarrow \rho Q^2\left(\frac{1}{A_2} - \frac{1}{A_1}\right) = \gamma A_1 z_1 - \gamma A_2 z_2$$

$$\Rightarrow \frac{\gamma}{g} Q^2\left(\frac{1}{A_2} - \frac{1}{A_1}\right) = \gamma\left(A_1 z_1 - A_2 z_2\right)$$

$$\Rightarrow \underbrace{\frac{Q^2}{gA_2} + z_2 A_2}_{F_2} = \underbrace{\frac{Q^2}{gA_1} + z_1 A_1}_{F_1}$$

← applicable for horizontal prismatic short reach channel for any type of X-section

Q. specific ফোrce or sp. momentum = $\boxed{F = \frac{Q^2}{gA} + \bar{z}A}$
আছে

z or $\bar{z}$

Q. specific force or sp. momentum = $\boxed{F = \frac{Q^2}{gA} + \bar{z}A}$
আছে (for any type of horizontal channel)

Lecture - 11

$zA \rightarrow$ pressure force per unit of water

For rectangular channel:

$h_1 \rightarrow$ Depth of flow before jump

$h_2 \rightarrow$ " " " after "

$$\boxed{A_1 = bh_1, A_2 = bh_2, z_1 = \frac{h_1}{2}} \star$$

$$\therefore \frac{Q^2}{gb^2} = \frac{h_1 h_2}{2}(h_1 + h_2)$$

$$\therefore \boxed{\frac{h_1}{h_2} = \frac{1}{2}\left(\sqrt{1+8F_{r2}^2} - 1\right)}$$

← applicable for horizontal rectangle channel.

Exam
Q. (Assignment) ① Derive this formula.

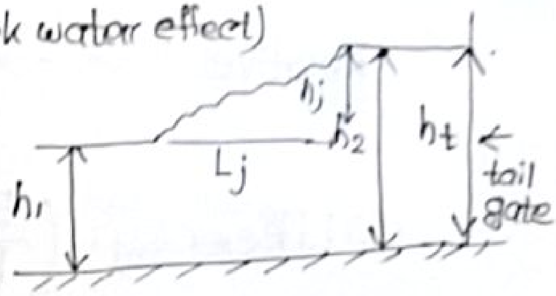
① নং এ ★ এটা বসালে,

$$\frac{Q^2}{gb^2} = \frac{h_1 h_2}{2}(h_1 + h_2)$$

$$\therefore \frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1+8F_{r1}^2} - 1\right)$$

যদি, $h_t > h_2 \rightarrow$ water U/S এ যাবে (back water effect)

$h_t < h_2 \rightarrow$ water D/S এ যাবে



$h_j \rightarrow$ height of jump $= h_2 - h_1$

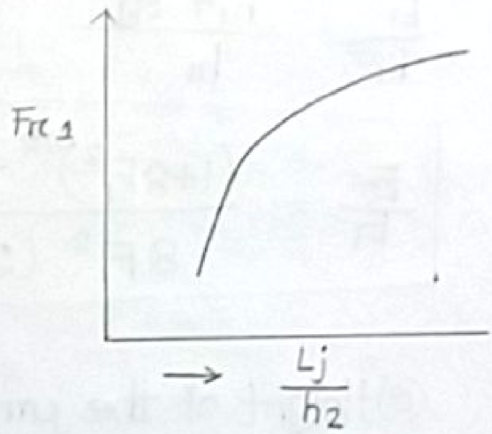
$L_j \rightarrow$ length " "

h_t = height of tailgate

L_j graph থেকে বের করা হয়

(Bradley- Peterka Curve)

$$\frac{L_j}{h_2} = 9.75\,(Fr_1 - 1)^{1.01}$$



□ Basic characteristic:

(A) · energy loss:

$$h_L = H_1 - H_2$$

$$= \left(Z_{b_1} + h_1 + \alpha_1 \frac{V_1^2}{2g}\right) - \left(Z_{b_2} + h_2 + \alpha_2 \frac{V_2^2}{2g}\right)$$

For horizontal channel, $Z_{b_1} = Z_{b_2}$

assuming $\alpha_1 = \alpha_2$

$$h_L = H_1 - H_2 = \left(h_1 + \frac{V_1^2}{2g}\right) - \left(h_2 + \frac{V_2^2}{2g}\right)$$

And, $A_1 = bh_1$, $A_2 = bh_2$, $V_1 = \frac{Q}{A_1}$, $V_2 = \frac{Q}{A_2}$

$$h_L = (h_1 - h_2) + \frac{Q^2}{2gb^2} \frac{(h_1 + h_2)(h_2 - h_1)}{h_1^2 h_2^2}$$

A-2 $\boxed{h_L = \frac{(h_1 - h_2)^3}{4 h_1 h_2}}$ For horizontal rectangle channel.

Exam Q. Derive the formula

9th week assignment
জমা দিবে (Sunday)

Relative loss $\rightarrow \dfrac{h_L}{E_1}$

(B) Efficiency: $\left(\dfrac{E_2}{E_1}\right)$

$$\frac{E_2}{h_2} = \frac{h_2 + \frac{v_2^2}{2g}}{h_2}$$

$$\frac{E_1}{h_1} = \frac{h_1 + \frac{v_1^2}{2g}}{h_1}$$

$$\boxed{\frac{E_2}{E_1} = \frac{(1+8F_1^2)^{3/2} - 4F_1^2 + 1}{8F_1^2\,(2+F_1^2)}}$$

$\boxed{A-3}$ Exam Q. Derive Formula.

(C) Height of the jump:

$$h_j = h_2 - h_1$$

$$\boxed{\text{Relative height} = \frac{h_j}{E_1}}$$

$$\boxed{\frac{h_j}{E_1} = \frac{\sqrt{1+8F_1^2} - 3}{2+F_1^2}}$$

$\boxed{A-4}$

Exam Q. $\rightarrow$ Derive Formula

$(a-b)^3 = a^3 - b^3 - 3ab(a-b)$

$(1+8F_{r_1}^2)^{3/2} - 1 - 3\sqrt{1+8F_{r_1}^2}\left(\sqrt{1+8F_{r_1}^2} - 1\right) + 4F_{r_1}^2$

$+4F_{r_1}^2 - 1$

$\sqrt{1+8F_{r_1}^2}$ $\quad 1+8F_{r_1}^2 - 3\sqrt{}$

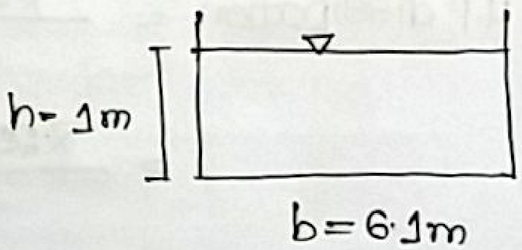
Lecture-12

Math

Water flows at a velocity of 6·1 m/s and a depth of 1m in a horizontal rectangular channel which is 6·1m wide. Find,

1) ~~Do~~ D/S depth needed to form jump
2) The type of jump
3) Height of jump
4) Length " "
5) Horse power dissipation in the jump
6) The efficiency of jump

$V = 6{\cdot}1\ m/s$



$$Fr = \frac{V_1}{\sqrt{gD_1}} = \frac{V}{\sqrt{gh}}$$

$$= \frac{6{\cdot}1}{\sqrt{9{\cdot}81 \times 1}}$$

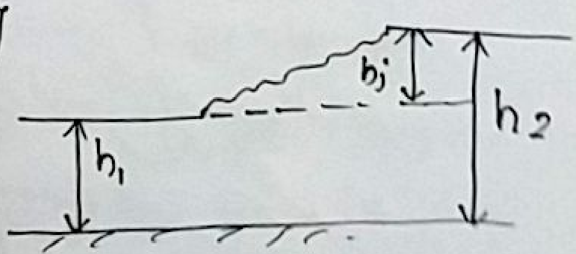
$$= 1{\cdot}95$$

$Q = VA$
$= (6{\cdot}1) \times (6{\cdot}1 \times 1)$
$= 37{\cdot}21\ m^3/s$

So, $\frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1+8F^2} - 1\right)$

$$\Rightarrow h_2 = \frac{1}{2} \times 1 \times \left\{\sqrt{1+8\times(1{\cdot}95)^2} - 1\right\}$$

$$= \boxed{2{\cdot}3\ m}$$



Type of Jump = $\boxed{\text{weak Jump}}$

$$h_j = h_2 - h_1 = 2.3 - 1 = \boxed{1.3m}$$

$$\frac{L_j}{h_2} = 9.75\ (F_{r_1} - 1)^{1.01}$$

$$\Rightarrow L_j = 9.75 \times 2.3 \times (1.95 - 1)^{1.01} = \boxed{21.3\ m}$$

Efficiency:

$$\frac{E_2}{E_1} = \frac{(1 + 8 \times 1.95^2)^{1.5} - 4 \times (1.95)^2 + 1}{8 \times (1.95)^2 \times (2 + 1.95^2)} = \boxed{91.72\%}$$

$$h_L = \frac{(h_1 - h_2)^3}{4 h_1 h_2} = \frac{(2.3 - 1)^3}{4 \times 2.3 \times 1} = 0.24m$$

$$\text{H.P dissipation} = \frac{7.22\ \rho Q\ h_L}{550}$$

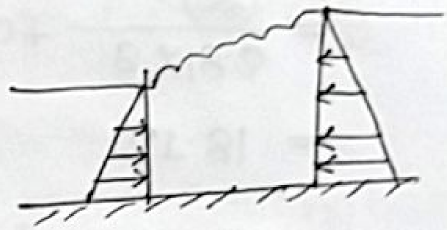
$$= \frac{7.22 \times 10^3 (\text{water}) \times 37.21 \times 0.24}{550}$$

$$= \boxed{117.23\ hp}$$

Math (horizontal non rectangular channel)

$$F_1 = F_2$$

$$\Rightarrow \frac{Q^2}{gA_1} + \bar{z}_1 A_1 = \frac{Q^2}{gA_2} + \bar{z}_2 A_2$$



Math

Water flows at a depth of 1m in a horizontal trapezoidal channel having a base width 5m and side slope 1:1 and $Q = 30\ m^3/s$. If a jump forms in the channel, compute

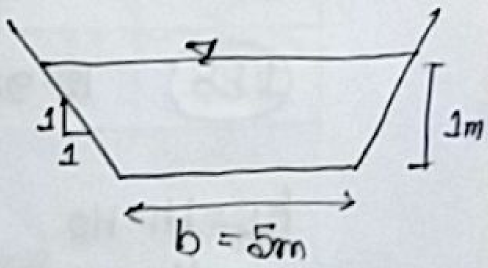
1) sequent depth
2) energy loss

মুখস্ত করবে

Sections	$\bar{z}$
Rectangular	$\frac{h}{2}$
Triangular	$\frac{h}{3}$
Trapezoidal	$h/6 \left(\frac{3b+2sh}{b+sh}\right)$
Circular	$\frac{2(d_0 h - h^2)^{3/2}}{3A} - \frac{d_0}{2} + h$
parabolic	$\frac{2h}{5}$

- আগে check করবো Jump হয় কিনা। U/S এর Fr বের করবো। সেটা >1 হলে Jump হবে।

$$A = (b + sh_1)\, h_1$$
$$= (5 + 1\times 1)\, 1$$
$$= 6\ m^2$$



$$T = b + 2sh = 5 + 2\times 1\times 1 = 7m$$

$$D_1 = \frac{6}{7} = 0.86\ m$$

$$V = \frac{Q}{A_1} = \frac{30}{6} = 5\ m/s$$

$$F_r = \frac{V}{\sqrt{gD_1}} = \frac{5}{\sqrt{9.81 \times 0.86}} = 1.72 > 1$$ (So, Jump হবে)

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$$F_1 = \frac{Q^2}{gA_1} + \bar{z}_1 A_1$$

$$\bar{z}_1 = \frac{h}{6}\left(\frac{3b+2sh}{b+sh}\right)$$

$$= \frac{1}{6}\left(\frac{3\times5+2\times1\times1}{5+1\times1}\right)$$

$$= 0.47\ m$$

$$= \frac{(30)^2}{9.81\times6} + 0.47\times6$$

$$= 18.12$$

$$F_1 = F_2 = \frac{Q^2}{gA_2} + \bar{z}_2 A_2 = 18.12$$

$$\Rightarrow \frac{(30)^2}{9.81\times A_2} + \bar{z}_2 A_2 = 18.12$$

[$h_2 > h_1$ হলে trial start করব]

$$A_2 = (5+h_2)h_2$$

$$T_2 = 5+2h_2$$

$$\bar{z}_2 = \frac{h_2}{6}\times\frac{3\times5+2\times1\times h_2}{5+1h_2} = \frac{h_2}{6}\times\frac{15+2h_2}{5+h_2}$$

h_2 (m)	A_2 (m^2)	$\bar{z}_2$ (m)	F_2
2	14	0.905	18.22
1.8	12.24	0.82	17.54
1.88	12.93	0.85	18.14

$$\boxed{\therefore h_2 = 1.88\ m}$$

$$h_L = H_1 - H_2$$

$$= \left(h_1 + \frac{v_1^2}{2g}\right) - \left(h_2 + \frac{v_2^2}{2g}\right)$$

$$= 1.88\ \boxed{0.12\ m}$$

$h_1 = 1m$

$h_2 = 1.88m$

$$V_1 = \frac{Q}{A_1} = 5m/s$$

$$V_2 = \frac{30}{12.93} = 2.32m/s$$

Stealing basin:

Artificial pet channel যেখানে hydraulic Jump হওয়াটাকে ensure করা হয়।

A short length of pet channel raised at the spillway or end of super critical flow

Q. What are the functions of stealing basin? (Stilling basin)

1) To promote the formation of Jump
2) To make the jump stable in one position
3) To make the jump as short as posibble.

Lecture - 13

□ Stilling basin :

Appurtenances of Stilling basin -

1) Chute blocks
2) sills
3) baffle piers

এদের function Q.

- Velocity যদি খুব high হয়, $F_r > 4.5$, তখন Baffle pier use করা যাবেনা। $V\uparrow$, $P\downarrow$, cavitation হবে।
- So, USBR - II → baffle pier use করা যাবে না
- USBR III → " " " " " ।

- Still basin এর design করা শিখতে হবে। এজন্য fig গুলো এঁকে দিতে হবে design অনুসারে।

- Stilling basin কি?
- এর কাজ
- Appurtenance গুলো কি কি?
- Appurtenance গুলোর function, কখন use করব এদের?
- Types of basin
- Design of basin
- Basin এর fig

~~**~~ আমাদের syllabus এ শুধু USBR II design আছে। অন্যগুলো নেই। কিন্তু fig সব basin এরই শিখতে হবে।

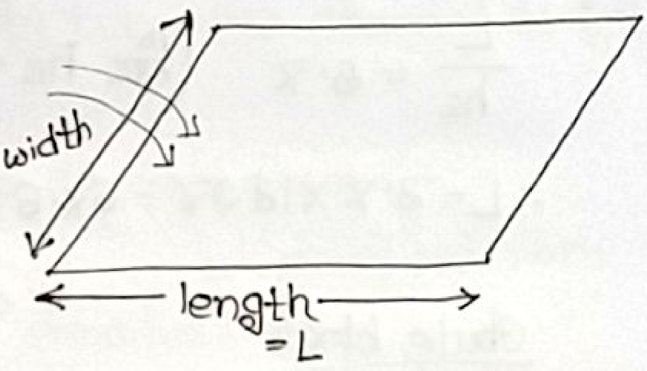
Example - 7.5

- $F_r > 4.5$ হলে কিনা check করতে হবে। যদি $F_r < 4.5$ হয় তবে USBR II design করতে হবে না।

$Q = 15870 \ m^3/s$

$B = 227.1 m$

$V_1 = 24.7 \ m/s$



$Q = A_1 V_1$

$\Rightarrow Q = B h_1 V_1$

$\Rightarrow h_1 = \frac{Q}{BV_1} = \frac{15870}{227.1 \times 24.7} = 2.83 m$ initial height

$$F_{r_1} = \frac{V_1}{\sqrt{g h_1}} = \frac{24.7}{\sqrt{9.81 \times 2.83}} = 4.7 > 4.5$$

$$\frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1+8F_{r_1}^2} - 1\right) =$$

$$\Rightarrow h_2 = h_1 \times \frac{1}{2}\left(\sqrt{1+8F_{r_1}^2} - 1\right) = 2.83 \times \frac{1}{2}\left(\sqrt{1+8\times 4.7^2} - 1\right)$$

$$= 17.4 m$$

5% allowance, বাড়িয়ে নিব,

$$\therefore h_2 = 17.4 + \left(\frac{5}{100} \times 17.4\right) = 18.27 \ m$$

Tail water level, $h_t = 17.26m$ (এটা maintain করতে হবে

∴ কিন্তু আমাদের $h_2 = 18.27m$ যেটা tail gate পার হয়ে যাচ্ছে।

তাই Datum 0.00 elevation এ set না করে একটু নিচে set করব।

কতটুকু নিচে $\rightarrow$ $18.27 - 17.26 = 1.01\ m$

$\frac{L}{h_2} = 3.7$ (ফিট Frc = 4.7) graph (c)

$\therefore L = 3.7 \times 18.27 = 67.6\ m$

Chute block

$S = h_1 = 2.83 m$

$w_1 = h_1 = 2.83 m$

$h = h_1 = 2.83 m$

Sill

$S = 0.15 h_2 = 0.15 \times 18.27 =$

$W = 0.15 h_2 = 0.15 \times 18.27 =$

$h = 0.2 h_2 = 0.2 \times 18.27 =$

- Hydraulic Jump
- যেখানে momentum eq^n use হয়
- Assumption
- Types of Jump

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Lecture -14

Design of Channel (Halim)

width, water depth, X-section বের করা → design

- Q এর এবং permissible velocity V এর উপর channel design depend করে।

- Velocity এর উপর depend করে 3 type of channel :

1) Rigid boundary channel (silting, scouring নাই, non-erodible channel)

→ silting: Velocity এর তুলনায় sediment বেশি হলে silting হয়।

→ scouring: channel এর ক্ষয় হওয়া, V বেশি হলে।

2) Mobile boundary channel : (scouring হবে, silting হবে না)

3) " " : (scouring, silting → both হবে)

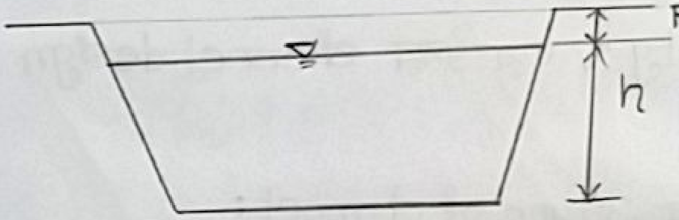
Q
- what is channel design?
- Types of channel
- what will be the shape of x-section?

- Q বেশি হলে, trapezoidal channel
- Q কম " , triangular, rectangular channel

* যেই channel design করব, তার F_r 0.3 → 0.4 এর মধ্যে vary করাবে। এবং sub critical flow maintain করে। এমনভাবে design করব যেন subcritical flow হয়। ∵ flow supercritical হলে flow unstable হয়ে যাবে, disturbance create হবে।

□ Freeboard:

Overflow কমানোর জন্য একটি allowance রাখা হয়। সেটিই হল freeboard



$F.B = \sqrt{ch}$ (unit in ft)

h = depth of water (in ft)

c = factor ($c = 1.5, Q \leq 20\ ft^3/s$)

($c = 2.5, Q > 300\ ft^3/s$)

Table → Q ও FB এর সম্পর্ক (মুখস্ত রাখবে)

Q (m^3/s)	<0.75	0.75-1.5	1.5-8.5	>85
F.B (m)	0.45	0.6	0.75	0.9

Q {
- FB কি?
- Roughness parameter কিসের উপর depend করে? (ch-4 এ আছে)
- কোন Type flow maintain করে channel design এ.

1) Rigid boundary channel:

1) seepage loss কমবে
2) channel area নির্ভুলভাবে maintain করা যায়। maintenance cost কমে
3) scouring কম হবে।
4) stability

concrete
stone
brick masonry
steel
cast iron
timber
glass, plastic
geo-textile

Q { · lining কি? এর সুবিধা, material

$0.6 \rightarrow 0.9$ m/s $\longrightarrow$ min permissible velocity

$2 \rightarrow 2.5$ m/s $\rightarrow$ max permissible velocity

☐ Best Hydraulic Section : (যার minimum perimeter থাকবে) যেন max. flow carry করে।

From Manning formula, $Q = \frac{1}{n} A R^{2/3} S^{1/2}$

$$Q \propto A R^{2/3}$$
$$= A\left(\frac{A}{P}\right)^{2/3}$$

$\therefore$ P কমালে Q বাড়ে, P কমালে lining কমবে, cost ও কমবে।

(17, 21 তারিখে class হবে না)

Lec-15

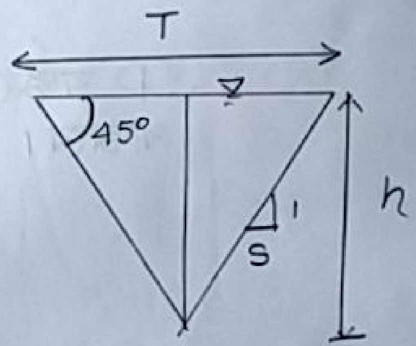
C.T { 24.5.17 (
14.5.17 (Sunday)

Syllabus → 1) Sp. energy and critical flow (14.5.17)
2) Hydraulic Jump (24.5.17)

Channel Design

for Triangular.

perimeter → smallest



$$A = \frac{1}{2} \times 2sh \times h = sh^2$$

$$P = 2\sqrt{h^2 + s^2h^2}$$

$$= 2h\sqrt{1+s^2}$$

$$= 2\sqrt{1+s^2} \cdot \sqrt{\frac{A}{s}}$$

$$\cancel{\frac{dP}{ds}(A \text{ constant}) = 2\sqrt{A}\left(-\frac{1}{2}\right)s^{-\frac{3}{2}} \sqrt{1+s^2} + 2\sqrt{\frac{A}{s}}}.$$

$$P^2 = 4(1+s^2)\frac{A}{s}$$

$$= 4A\left(\frac{1}{s} + s\right)$$

$$\therefore 2P\frac{dP}{ds} = 4A(1 + \ln s)$$

$$\Rightarrow \frac{dP}{ds} = \frac{2A}{P}(1+\ln s) = \frac{\cancel{2}\cancel{A}(1+\ln s)\sqrt{A}}{\cancel{2}\sqrt{1+s^2}\,\cancel{\sqrt{A}} \cdot \frac{1}{\sqrt{s}}}$$

$$= \frac{\sqrt{As}(1+\ln s)}{\sqrt{1+s^2}}$$

$$\frac{dP}{ds} = 0$$

$$\Rightarrow \sqrt{As}\,(1+\ln s) = 0$$

$$\Rightarrow \sqrt{s} = 0 \quad \text{or} \quad 1+\ln s = 0$$

$$\Rightarrow \ln s = -1$$

$$\Rightarrow s = 0.36$$

$\boxed{s = 1}$ আসবে!

$$P^2 = 4(1+s^2)\left(\frac{A}{s}\right)$$

$$= 4A\left(s+\frac{1}{s}\right)$$

$$\Rightarrow 2P\frac{dP}{ds} = 4A\left(1-\frac{1}{s^2}\right)$$

$$\Rightarrow \frac{dP}{ds} = \frac{2A}{P}\left(\frac{s^2-1}{s^2}\right)$$

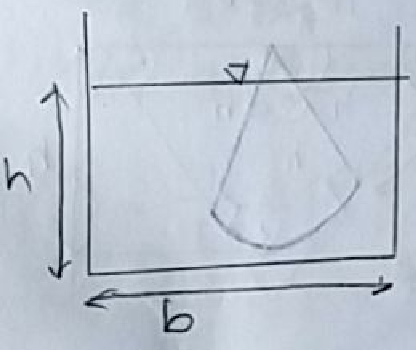
Now, $\frac{dP}{ds} = 0$

$\therefore s^2 - 1 = 0$

$\therefore \boxed{s = 1}$

Q. show that, for best hy. sec in triangular case angle 45°.

For rectangular:



$$P = b + 2h$$

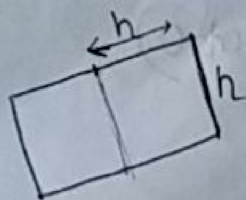
$$A = bh \rightarrow b = \frac{A}{h}$$

$$\therefore P = \frac{A}{h} + 2h$$

$$\frac{dP}{ds} = -\frac{A}{h^2} + 2 = 0$$

$$\therefore A = 2h^2$$

$$\boxed{\therefore b = 2h}$$



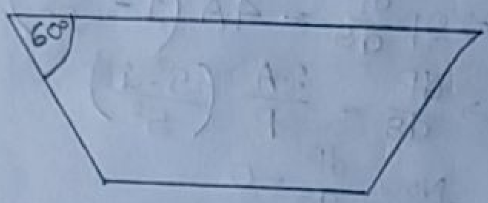
b^2

hx

Example - 5·2

g_m For trapezoidal channel :

[Table - Geometric element of best hydraulic section]



Practically rigid boundary channel :

$Q < 55\ m^3/s \rightarrow$ triangular / rectangular channel design

$Q > 55\ m^3/s \rightarrow$ trapezoidal channel

Design of practically lined channel ;

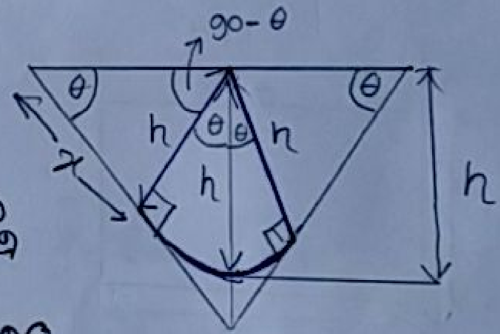
1) Triangular :

$$P = (h \cot\theta \times 2) + 2h\theta$$

$$P = 2h(\theta + \cot\theta) \rightarrow \text{radian mode}$$

$$A = 2 \times \frac{1}{2} \times h \times h\cot\theta + \frac{\pi h^2}{2\pi} \times 2\theta$$

$$A = h^2(\cot\theta + \theta)$$



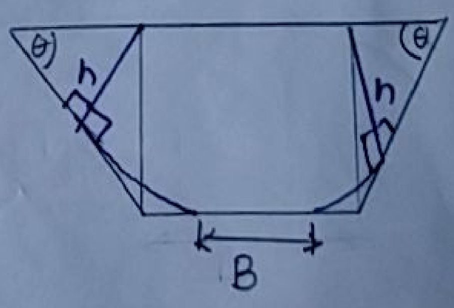
$$S = r\theta = h \cdot (2\theta) = 2h\theta$$

2) Trapezoidal :

$$P = B + 2h\cot\theta + 2 \times \frac{2\pi h}{2\pi}\theta$$

$$= B + 2h(\theta + \cot\theta)$$

$$A = Bh + h^2(\theta + \cot\theta)$$



Math

A channel lined with concrete,

longi. slope = 1 in 3600

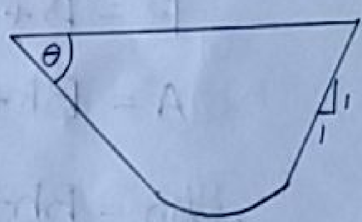
Side slope = 1:1

$n = .013$

$Q = 35\ m^3/s$

Determine A, P.

$$\theta = 45^\circ = \frac{45\pi}{180}$$



$$P = 2h\,(\theta + \cot\theta)$$

$$P = 2\times h\,(0.78 + 0.999)$$

$$= 3.56\,h$$

$$A = h^2(\theta + \cot\theta) = 1.78\,h^2$$

$$R = \frac{A}{P} = \frac{1.78h^2}{3.56h} = \frac{h}{2}$$

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

$$\Rightarrow 35 = \frac{1}{0.013} \times 1.78h^2 \times \left(\frac{1}{3600}\right)^{1/2} \left(\frac{h}{2}\right)^{2/3}$$

$$\Rightarrow 0.26 = h^2 \times h^{2/3} \times 0.0105$$

$$\therefore h^{8/3} = 24.76$$

$$\boxed{\therefore h = 33\,m}$$

Math (fig আঁকতেই হবে)

long. slope = 1 in 3600

side slope = 1 : 1

$Q = 100\ m^3/s$

$n = 0.013$

$v = 2\ m/s$

$A = \frac{Q}{v} = \frac{100}{2}$

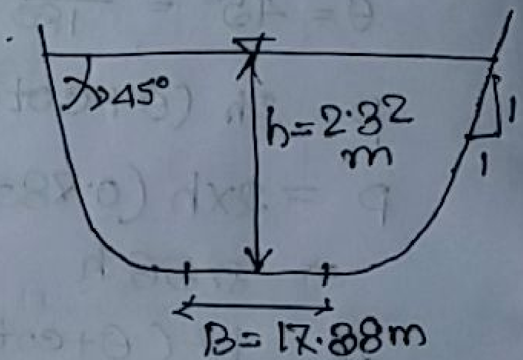
$= 50\ m^2$

$\theta = 45° = \frac{\pi}{4}$

$P = B + 3.571h$

$A = Bh + 1.785h^2$

$\therefore 50 = Bh + 1.785h^2$



$R = \frac{A}{P}$

$Q = \frac{1}{n} A R^{2/3} S^{1/2}$

$\Rightarrow 100 = \frac{1}{0.013} \times 50 \times R^{2/3} \times \left(\frac{1}{3600}\right)^{1/2}$

$\therefore R = 1.95\ m$

$\therefore P = \frac{A}{R} = \frac{50}{1.95} = 25.66 m$

$\therefore 25.66 = B + 3.571h \Rightarrow B = 25.66 - 3.571h$

$50 = Bh + 1.785h^2$

$\Rightarrow 50 = 25.66h - 3.571h^2 + 1.785h^2$

$\Rightarrow \cdot 1.79h^2 - 25.66h + 50 = 0$

$\therefore h = 12,\ 2.32$

$h = 2.32\,m \rightarrow B = 17.38\,m$ ✓

$h = 12\,m \rightarrow B = -17.19\,m$

Halim Sir এর বই

Anika Madam → Chapter : 1, 2 (just governing eqn of OCF), 3, 5, 7

Sabbir Sir → Chapter : 1, 4, 6 → upto article 6.3

4 → upto example 4.12

** লেকচার খাতায় অংক ভুল তোলা থাকলে, হালিম স্যারের বই দেখতে হবে। Teacher রা সব math এই বই থেকেই করিয়েছেন।

2014-15

4 (a) For trapezoidal channel,

$$A = (b+sh)h \quad \cdots\cdots (1)$$

$$\Rightarrow b = \frac{A}{h} - sh$$

$$\therefore P = b + 2h\sqrt{1+s^2} = \frac{A}{h} - sh + 2h\sqrt{1+s^2}$$

$$= \frac{A}{h} + h\left(2\sqrt{1+s^2} - s\right)$$

$$\therefore \frac{dP}{dh} = \frac{-A}{h^2} + 2\sqrt{1+s^2} - s$$

$$\frac{dP}{dh} = 0$$

$$\Rightarrow 2\sqrt{1+s^2} - s = \frac{A}{h^2} \qquad \therefore A = h^2\left(2\sqrt{1+s^2} - s\right) \cdots\cdots (2)$$

From (1) and (2), $(b+sh)h = h^2\left(2\sqrt{1+s^2} - s\right)$

$$\Rightarrow b = h\left(2\sqrt{1+s^2} - s - s\right) = 2h\left(\sqrt{1+s^2} - s\right)$$

$$\therefore b = 2h\left(\sqrt{1+s^2} - s\right)$$

Now, $P = b + 2h\sqrt{1+s^2}$

$$= 2h\left(\sqrt{1+s^2} - s + \sqrt{1+s^2}\right)$$

$$P = 2h\left(2\sqrt{1+s^2} - s\right)$$

$$\Rightarrow P^2 = 4h^2\left(2\sqrt{1+s^2} - s\right)^2 \quad \cdots\cdots (3)$$

From (2), putting values of h^2 in (3),

$$P^2 = 4 \cdot \frac{A}{2\sqrt{1+s^2} - s} \cdot \left(2\sqrt{1+s^2} - s\right)^2$$

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$$\Rightarrow p^2 = 4A\left(2\sqrt{1+s^2} - s\right)$$

$$\Rightarrow 2p\frac{dP}{ds} = 4A \cdot \left(2 \cdot \frac{2s}{2\sqrt{1+s^2}} - 1\right)$$

$$\Rightarrow 2p\frac{dP}{ds} = 4A\left(\frac{2s}{\sqrt{1+s^2}} - 1\right)$$

$$\Rightarrow \frac{dP}{ds} = \frac{2A}{P}\left(\frac{2s}{\sqrt{1+s^2}} - 1\right)$$

$$\because \frac{dP}{ds} = 0$$

$$\Rightarrow \frac{2s}{\sqrt{1+s^2}} - 1 = 0$$

$$\Rightarrow 2s = \sqrt{1+s^2}$$

$$\Rightarrow 4s^2 = 1+s^2$$

$$\Rightarrow 3s^2 = 1$$

$$\therefore s = \frac{1}{\sqrt{3}}$$

$$\tan\theta = \frac{1}{s} = \frac{1}{1/\sqrt{3}} = \sqrt{3} = \tan 60^\circ$$

$$\therefore \theta = 60^\circ = \frac{60\pi}{180} = 1.0472 \text{ rad.}$$

$$\therefore A = h^2\left(2\sqrt{1+(1/3)} - \frac{1}{\sqrt{3}}\right) = 1.732\,h^2$$

$$\therefore \boxed{A = 1.732\,h^2}$$

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4(b) (ii) For concrete, $n = 0.013$

$$S_o = 1/2 = 0.5$$

$$Q = 1.5 \, m^3/s$$

For best hydraulic rectangular channel section,

$$b = 2h$$

$$A = b \times h = 2 \times h \times h = 2h^2$$

$$P = b + 2h = 2h + 2h = 4h$$

$$R = \frac{A}{P} = \frac{2h^2}{4h} = \frac{h}{2}$$

So, $Q = \frac{1}{n} A R^{2/3} \sqrt{S_o}$

$$\Rightarrow AR^{2/3} = \frac{Qn}{\sqrt{S_o}} = \frac{1.5 \times 0.013}{\sqrt{0.5}}$$

$$\Rightarrow 2h^2 \times \left(\frac{h}{2}\right)^{2/3} = 0.0276$$

$$\Rightarrow h^{8/3} = 0.0219$$

$$\therefore h = 0.24 \, m$$

$$\therefore b = 2h = 0.48 \, m$$

Freeboard $= 0.60 \, m$

So, Total height $= 0.60 + 0.24 = \boxed{0.84 \, m}$

$$\boxed{b = 0.48 \, m}$$

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5 (d) $v = 1 + 2\frac{z}{y}$, $y = 5m$

(i) Here, $v = 1 + 2\cdot\frac{z}{y}$

$$V = \frac{\int v\, dA}{A} = \frac{\int v\cdot(b\cdot dz)}{b\times y} = \frac{\int_0^5 v\, dz}{y}$$

$$= \frac{\int_0^5 \left(1+\frac{2z}{5}\right)dz}{5} = 2\, m/s$$

$P = b + 2h \approx b$

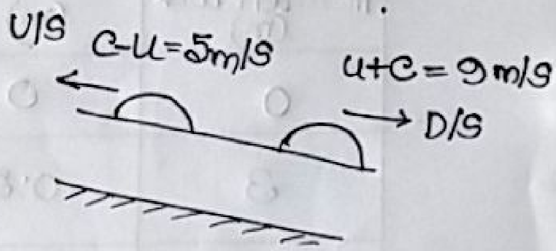
$$F_r = \frac{V}{\sqrt{gD}} = \frac{2}{\sqrt{gy}} = \frac{2}{\sqrt{9.81\times 5}}$$

$$= 0.29 < 1$$

For wide river, $D = \frac{A}{T} = \frac{b\times y}{b} = y$

Flow is subcritical.

Now, $c = \sqrt{gD} = \sqrt{9.81\times 5} = 7\, m/s$



(A) $u + c = V + c = 2 + 7 = 9\, m/s$

$c - u = 7 - 2 = 5\, m/s$

(ii) $q = \frac{Q}{b} = \frac{AV}{b} = \frac{byV}{b} = yV = 5\times 2 = 10\, m^2/s$ (Ans)

(iii) Flow is subcritical turbulent.

$$Re = \frac{VR}{\nu} = \frac{2\times(A/P)}{\nu} = \frac{2\times(bh/b)}{\nu} = \frac{2h}{\nu}$$

$$= \frac{2\times 5}{10^{-6}} = 10^7 > 12{,}500$$

(iv) $$\alpha = \frac{\int_0^5 v^3\, dz}{V^3 y} = \frac{\int_0^5 \left(1+\frac{2z}{5}\right)^3 dz}{(2)^3\times 5} = 1.25 \text{ (Ans)}$$

$$\beta = \frac{\int_0^5 v^2 dz}{V^2 y} = \frac{\int_0^5 \left(1+\frac{2z}{5}\right)^2 dz}{(2)^2\times 5} = 1.083$$ (A)

5 (e) $V = a + bN$

where, $a, b \rightarrow$ constant

$N \rightarrow$ rev/min

So, $0.293 = a + b \times (105/2)$ .... ①

$0.342 = a + b \times (125/2)$ .... ②

$\therefore$ Solving ① and ②, $\boxed{\begin{array}{l} a = 0.03575 \\ b = 4.9 \times 10^{-3} \end{array}}$ Ⓐ

Distance from Left bank (m)	Total depth = y (m)	width (m) Ⓐ	current meter location from water surface (m) Ⓐ
0	0	0	0
3	0.58	3	$0.6y = 0.348$
6	2.5	2.5	$0.8y = 2$ $0.2y = 0.5$
8	6.3	2	$0.8y = 5.04$ $0.2y = 1.26$
10	0.8	2	$0.8y = 0.64$ $0.2y = 0.16$
12	0	0	0