EWCE 361 — SB

chap - 5.6.7

chap-5 (Design of channels)

given discharge satisfy kote hbe

channel

1. rigid boundary - non-erodible
2. mobile " - erodible, only erosion
3. alluvial " - scouring, silting (depositing)

discharge value beshi — trapezoidal channel
kom — triangular "

roughness charse depend on

side slope of channel

$$Fr = \frac{V}{\sqrt{g D}}$$

Froude num

Fr = 1 — critical
Fr < 1, sub-
Fr > 1, super

Fr → 0.3 to 0.4

Freeboard

Lining — nich theke freeboard er half porjonto

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rigid boundary

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

Chezy, $Q = CA R^{1/2} S^{1/2}$

non-erodable — no sediments, clear water

Regular description

advantage, def, theory

---

min permissible velocity — (0.61 to 0.91) m/s

max - - - cant be > 2 m/s

Best hydraulic section — math must

{ discharge max
  hydraulic perimeter max
  P min

$Q = CAR^{\frac{1}{2}} S^{1/2}$

Q → max, $R^{\frac{1}{2}}$ → max

$R = \frac{A}{P}$ → min

e) Perimeter kom but discharge ta beshi nite hoi

- $B = 2h$, $s = 1$, $s = 1/\sqrt{3}$
  - prove can come also derivation

P 92 — table er value gula mukhosto (trapezoidal must)

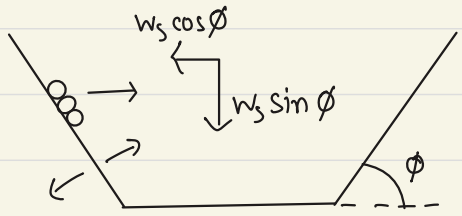
Ex-5.1, P 93



Erodible channel which scour but do not shear — shear on tractive force method

$\tau_0 > \tau_c \rightarrow$ channel scour

$\tau_0 \approx \tau_c \rightarrow$ preferred



$\tau_0 = \phi g R S_0$

$= \gamma R S_0$

$= \gamma h S_0$

Shear develops at both boundary & bottom; at bottom is highest

graph be provided ← { max at btm; at size: 0.75 (max) though not relevant for us

Shear stress ratio [derivation not be asked]

Shear stress at side slope

$\tau_s = \cdots$

Shear stress at bottom

$\tau_b = \cdots$

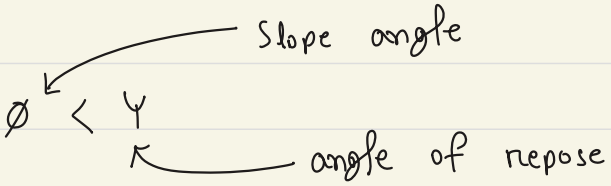
Ratio, $K = \frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\sin^2\phi}{\sin^2\psi}}$

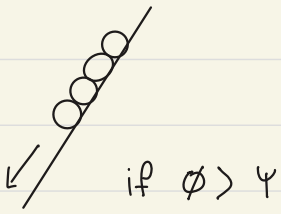
Angle of repose

$\tau_b \leq 0.4 d_{75}$ — no erosion from bed, allow from boundary

Shield curve... not req

Yalin (P 95) ... " "





Procedure for designing trapezoidal channel

[convert d_{75} to inch]

graph in inch

~~ØØØ~~ Ex. 5.6

$S_0 = 1/1000 = 0.002$

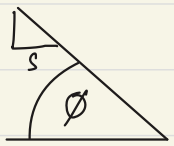
$d_{75} \rightarrow 0.98$ in

$\psi \rightarrow 33°$ [From fig] ← arbitrary

Assume, $S = 2$

$b/h = 4$ ← advised

$\phi = \cdots = 26.56°$



$\cot \phi = S$

$\Rightarrow \phi = \cot^{-1}(S)$

max shear =

$K = \cdots$

$\tau_b = \cdots$

$\tau_s = \cdots$

$b = \cdots$

if not fulfilled → trial & error

b/h ← change b; h → const

mid →

example type math
No derivation (not the style

L04 30/12

Alluvial channel: Regime approach

Formula by Kennedy: $V_0 = 0.546 h^{0.64}$ ← no width, limitation not used

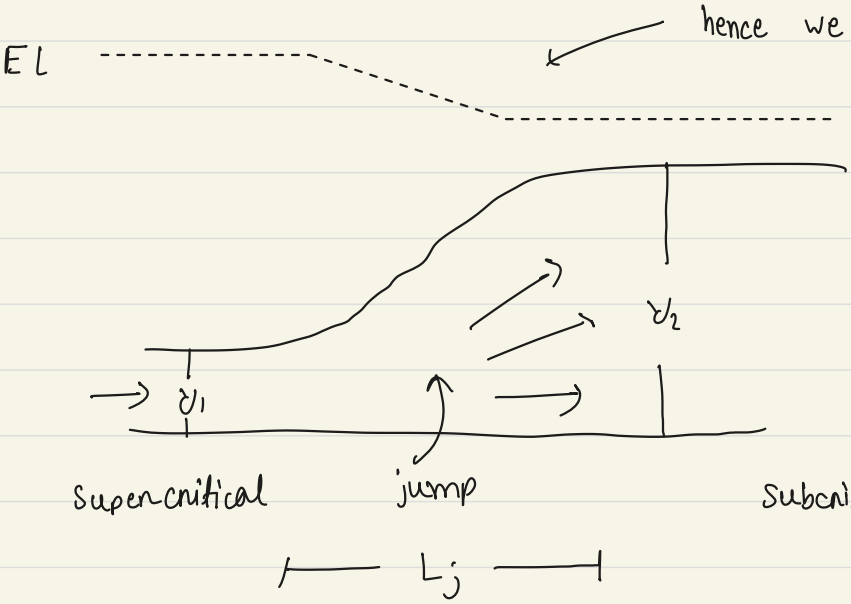
Lacey's regime: two regime; four formula be given

For alluvial channel assume side slope 2:1

Chapter 7 Hydraulic jump

use momentum eqn

hence we don't use energy eqn for this



main principle reduce kinetic energy

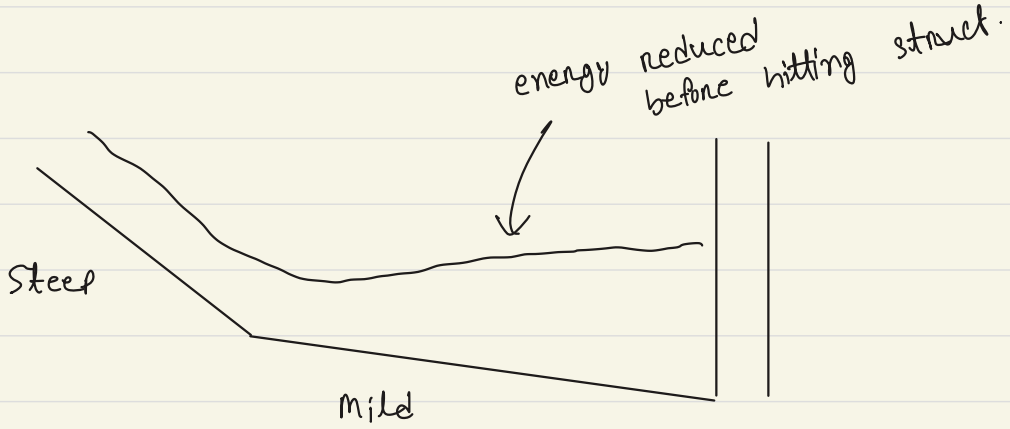


Use of hydraulic jump (total 7 points)

Types of hydraulic jump

As per USBR, based on F_{r1}

1. Undular jump
2. Weak jump
3. Oscillating jump
4. Steady jump
5. Strong jump



Sequent depth

Momentum eqn: $\rho Q(\beta_2 V_2 - \beta_1 V_1) = F_{p1} - F_{p2} + W\sin\theta - F_f$ (0, ~0)

$$\rightarrow \frac{Q^2}{gA_1} + \bar{z}_1 A_1 = \frac{Q^2}{gA_2} + \bar{z}_2 A_2 \quad \leftarrow \text{Specific force eqn}$$

$$F_1 = F_2 ; \quad F = \frac{Q^2}{gA} + \bar{z}A$$

← pressure force

← momentum force

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

Length of jump

$$\frac{L_j}{h_1} = 9.75 (Fr_1 - 1)^{1.01}$$ [be given]

Location of the jump

trial & error method for real life scenario

Specific energy →

$h_L = \frac{(h_2 - h_1)^3}{4 h_1 h_2}$ [energy loss]

$h_L / E_1 = 1 - E_2 / E_1$ [relative loss]

Eqn 7.18 → be given

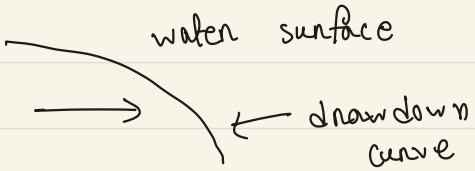
☆☆☆ Example 7.1

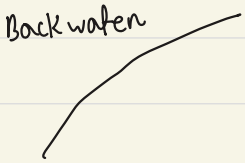
☆☆☆ Example 7.2

☆☆ Example 7.3

L06 27/01

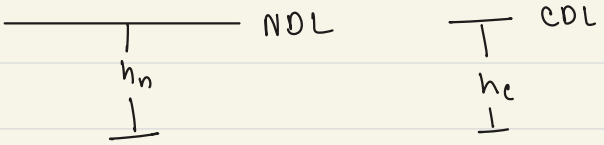
Gradually varied flow

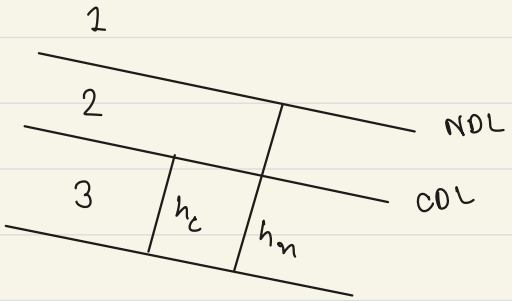




$Q = \frac{1}{n} A R^{2/3} S^{1/2}$

$\hookrightarrow K$





mild →

zone 1 → backwater curve

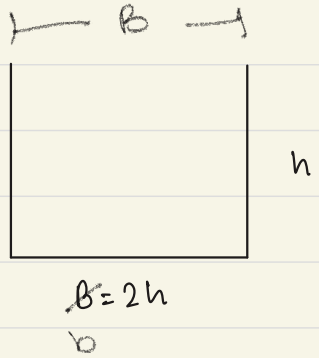
2 → drawdown

steep → CDL above NDL

Rough / mid term 15/02

Geometric elements of best hydraulic sections:

Rectangular →



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

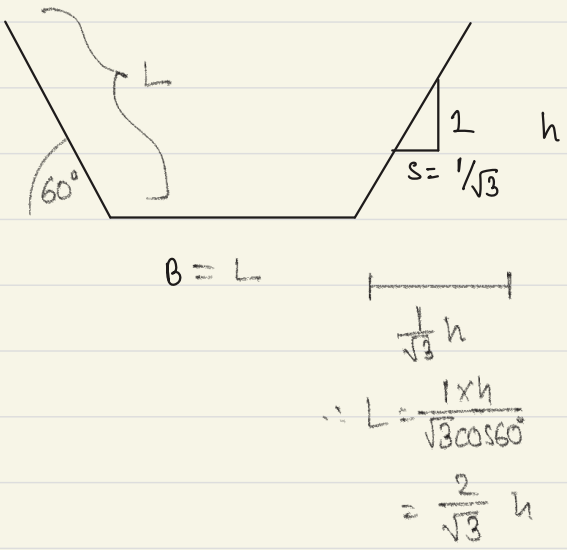
$P = 2h + 2h = 4h$

$R = A/P = 1/2\,h$

$T = 2h$

$D = A/T = h$

Trapezoidal →



$A = Bh + sh \times h$

$= \frac{2}{\sqrt{3}} h^2 + 1/\sqrt{3}\, h^2$

$= \sqrt{3}\, h^2$

$P = \frac{2}{\sqrt{3}} h + 2 \times \frac{2}{\sqrt{3}} h$

$= 2\sqrt{3}\, h$

$\therefore L = \frac{1 \times h}{\sqrt{3} \cos 60^\circ}$

$= \frac{2}{\sqrt{3}} h$

$R = h/2$

$T = 2/\sqrt{3}\, h + 2\,\frac{1}{\sqrt{3}} h = \frac{4}{\sqrt{3}} h$

$D = 3/4\, h$

Ex. 5.3

Given, trapezoidal channel

$Q = 20\ m^3/s$

$S_0 = 1:1000$

$n = 0.025$

Manning's eqn:

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

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

$$\Rightarrow AR^{2/3} = \frac{nQ}{\sqrt{S_0}}$$

$$= \frac{0.025 \times 20}{\sqrt{1/1000}} = 15.81$$

And, $A = Bh + Sh^2$

$$= \frac{2}{\sqrt{3}} h^2 + \frac{1}{\sqrt{3}} h^2$$

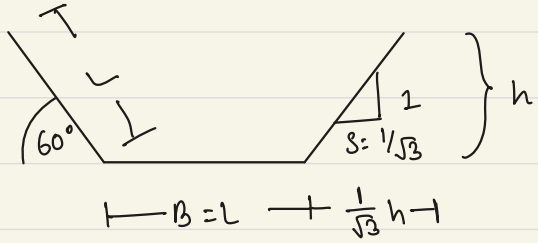
$$= \sqrt{3} h^2$$

$$P = 3 \times \frac{2}{\sqrt{3}} h = 2\sqrt{3} h$$

$$\therefore R = h/2$$

Thus, $\sqrt{3} h^2 \times \left(\frac{h}{2}\right)^{2/3} = 15.81$

$$\Rightarrow h = 2.73\ m$$



$$L = \frac{1}{\sqrt{3} \cos 60°} h$$

$$= \frac{2}{\sqrt{3}} h$$

$$T = \frac{2}{\sqrt{3}} h + \frac{2}{\sqrt{3}} h = 6.3\ m$$

$$B = \frac{2}{\sqrt{3}} h = 3.15\ m$$

$$S = 1/\sqrt{3} = 0.577$$

$\therefore A = \sqrt{3} h^2 = \sqrt{3} \times 2.73^2 = 12.91\ m^2$

$\therefore V = Q/A = 20/12.91 = 1.55\ m/s$ [$\geq 0.91\ m/s$ & $< 2\ m/s$]

$$F_R = \frac{V}{\sqrt{gD}} = \frac{1.55}{\sqrt{9.81 \times 2.05}} = 0.35$$ $\left[D = \frac{A}{T} = \frac{12.91}{6.3} = 2.05 m\right]$

Freeboard = 0.77 m → total depth = 3.5 m

Practical rigid boundary channel section

Triangular: $A = h^2(\phi + \cot\phi)$

$P = 2h(\phi + \cot\phi)$

Trapezoidal: $A = bh + h^2(\phi + \cot\phi)$

$P = b + 2h(\phi + \cot\phi)$

Ex. 5.4 $S_0 = 1:3600$; $s = 1:1$; $n = 0.013$

(a) For $Q = 35\ m^3/s$ [$< 55\ m^3/s \rightarrow$ triangular section]

$\phi = \tan^{-1}(1/s)$

$= 0.785^c$

$A = h^2(\phi + \cot\phi) = 1.786\ h^2$

$P = 2h(\phi + \cot\phi) = 3.572h$

$R = A/P = 0.5h$

Manning's formula:

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

$$\Rightarrow 35 = \frac{1}{0.013} \times 1.786h^2 \times (0.5h)^{2/3} \times \left(\frac{1}{3600}\right)^{1/2}$$

$$\Rightarrow h = 3.6\ m$$

(b) $Q = 100\ m^3/s$ [$> 55\ m^3/s \rightarrow$ trapezoidal]

$v = 2\ m/s$

$\therefore A = Q/v = 50\ m^2$

Manning's eqn:

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

$$\Rightarrow 100 = \frac{1}{0.013} \times 50 \times R^{2/3} \left(\frac{1}{3600}\right)^{0.5}$$

$$\Rightarrow R = 1.95\ m$$

Again, $R = A/P$

$$\therefore P = A/R = 25.64\ m$$

Also, $P = b + 2h(\phi + \cot\phi) = 25.64 = b + 3.572h$ —(i)

$A = bh + h^2(\phi + \cot\phi) = 50 = bh + 1.786h^2$ —(ii)

(ii) − (i)h $\Rightarrow bh + 1.786h^2 - bh - 3.572h^2 = 50 - 25.64h$

$$\Rightarrow -1.786h^2 + 25.64h = 50$$

$$\Rightarrow h = 12.03,\ 2.33\ m$$

Corresponding $b = -17.33,\ 17.32\ m$

$\therefore b, h = 17.32\ m,\ 2.33\ m$

Ex. 5.5 $n = 0.013$; $S_0 = 1:3600$; $Q = 100\ m^3/s$

(a) $b = 6\ m$; $s = 1:1$

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

$$\Rightarrow AR^{2/3} = \frac{nQ}{\sqrt{S_0}} = \frac{0.013 \times 100}{\sqrt{1/3600}} = 78$$

Trial & err:

$A = bh + sh^2$; $P = b + 2\sqrt{(sh)^2 + h^2}$; $R = A/P$

b	h	A	P	R	$AR^{2/3}$
6	2	16	11.656	1.37	19.76
	4	40	17.31	2.31	69.9
	5	55	20.14	2.73	107.44
	4.24	43.42	17.99	2.41	78.11

$\therefore h = 4.24\ m$

(b) $s = 1:1$

$$AR^{2/3} = \frac{nQ}{\sqrt{S_0}} = 78$$

$A = \sqrt{3}\, h^2$

$R = 0.5h$

$$\Big\} \quad 78 = \sqrt{3}\, h^2 \times (0.5h)^{2/3} \Rightarrow h = 4.96\ m$$

(c) $$AR^{2/3} = A\left(\frac{A}{P}\right)^{2/3} = \frac{A^{5/3}}{P^{2/3}} = \frac{(bh + sh^2)^{5/3}}{\left(b + 2\sqrt{(sh)^2 + h^2}\right)^{2/3}}$$

$\Rightarrow 78 = \cdots \Rightarrow h = 3.69\ m$

LO7 24/02

Ø Ø Ø Sketch of flow profile NDL → Normal Depth Line

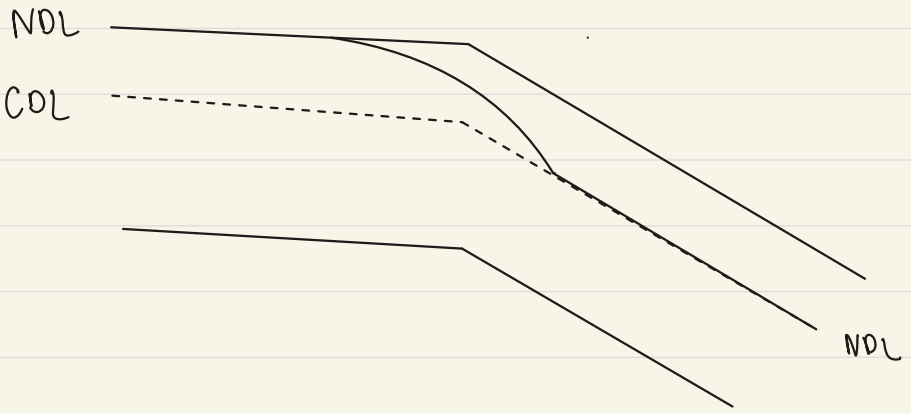
m_1	S_1	C_1		
m_2	S_2	C_2	H_2	A_2
m_3	S_3	C_3	H_3	A_3

would be asked to sketch only; not explain

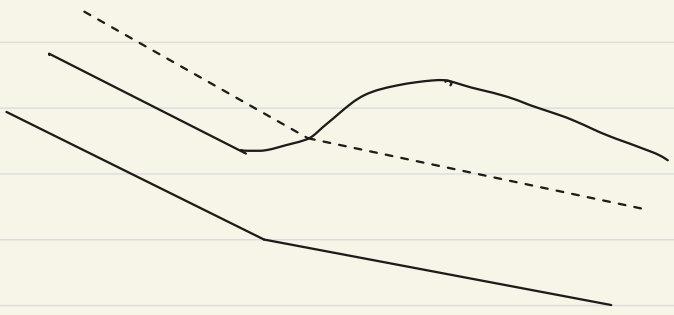
Example of flow profile

Ø Ø Ø Flow profiles in serial arrangement

1. - - -



mild – steep

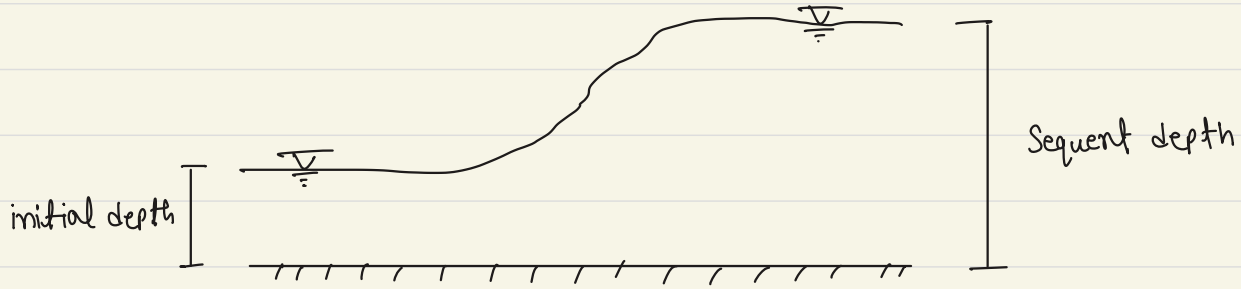


Example 6.1

Example 6.2 steeper mild

Rough / CT-2 01/03

Hydraulic jump



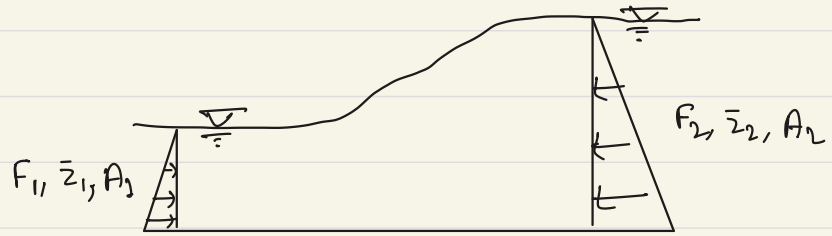
Uses:

(1) Dissipation of energy: to prevent scouring on d/s structures
(2) Increase depth: for irrigation and flow distribution purposes.
(3) Increase discharge: under sluice, by increasing depth, free-flow condition prevails
(4) Reduce uplift pressure: by increasing water weight above apron
(5) Mixing of chemicals: sequent flow is turbulent & chaotic, suitable for mixing
(6) Aeration of flows: from city water supplies
(7) Removal of air pockets: from city water supplies.

Types:

Fr range	Type
1 - 1.7	Undulan jump
1.7 - 2.5	Weak jump
2.5 - 4.5	Oscillating jump
4.5 - 9	Steady jump
> 9	Strong jump

Sequent depth:



Momentum eq^n,

$$\rho Q(\beta_2 U_2 - \beta_1 U_1) = F_1 - F_2 + \cancel{W\sin\theta}^{\,0} - \cancel{F_f}^{\,0}$$

$$\Rightarrow \rho Q\left(1\times\frac{Q}{A_2} - 1\times\frac{Q}{A_1}\right) = \rho g \bar{z}_1 A_1 - \rho g \bar{z}_2 A_2$$

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

$$\Rightarrow \frac{Q^2}{gA_2} + A_2\bar{z}_2 = \frac{Q^2}{gA_1} + A_1\bar{z}_1 \quad \leftarrow \text{Specific force eq}^n$$

$$\Rightarrow F_2 = F_1 \;; \quad F = \underbrace{\frac{Q^2}{gA}}_{\text{momentum force}} + \underbrace{A\bar{z}}_{\text{pressure force}}$$

For rectangular channel,

$$\frac{h_1}{h_2} = \frac{1}{2}\left[\sqrt{1+8F_{r_2}^2} - 1\right]$$

Length of jump: Hor. distance from the face of the jump to a point immediately downstream of the roller

$$\frac{L_j}{h_1} = 9.75\,(Fr_1 - 1)^{1.01}$$

Energy loss:

$$h_L = E_1 - E_2 = \left(h_1 + \frac{v_1^2}{2g}\right) - \left(h_2 + \frac{v_2^2}{2g}\right)$$

$$= \dots$$

$$= \frac{(h_2 - h_1)^3}{4 h_1 h_2} \qquad \text{[for rect channel]}$$

Relative loss:

$$\frac{h_L}{E_1} = 1 - \frac{E_2}{E_1}$$

$$\frac{E_2}{E_1} = \frac{(1+8Fr_1^2)^{3/2} - 4Fr_1^2 + 1}{8Fr_1^2(2+Fr_1^2)}$$

Height of jump:

$$\frac{h_j}{h_1} = \frac{1}{2}\left[\sqrt{1 + 8\,Fr_1^2} - 3\right]$$

$$h_j = \frac{\sqrt{1+8\,Fr_1^2} - 3}{2 + Fr_1^2} \times E_1 \quad \rightarrow \quad \frac{h_j}{E_1} \rightarrow \text{relative jump}$$

Example 7.1 : $b = B = 6m$; $h = D = 0.52m$; $v = 15.2\ m/s$

(i) $F_{r_1} = \frac{v}{\sqrt{gD}} = \frac{15.2}{\sqrt{9.81 \times 0.52}} = 6.73 \rightarrow$ Steady jump

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

$\Rightarrow \frac{h_2}{0.52} = \frac{1}{2}\left[\sqrt{1+8\times 6.73^2} - 1\right] = 4.7\ m$

(iii) $h_L = \frac{(h_2 - h_1)^3}{4h_1h_2} = \frac{(4.7-0.52)^3}{4\times 4.7 \times 0.52} = 7.47\ m$

$HP = \frac{\rho g Q h_L}{76.04} = \frac{1000 \times (6\times 0.52 \times 15.2) \times 7.47}{76.04} = 4658\ HP$

(iv) $E = \frac{(1+8F_{r_1}^2)^{3/2} - 4F_{r_1}^2 + 1}{8F_{r_1}^2(2+F_{r_1}^2)}$; $F_{r_1} = 6.73$

$= 0.39 = 39\%$

(v) $\frac{h_j}{E} = \frac{\sqrt{1+8F_{r_1}^2} - 3}{2+F_{r_1}^2} = 0.34 = 34\%$

(vi) $\frac{L_j}{h_1} = 9.75(F_{r_1} - 1)^{1.01}$; $h_1 = 0.52$

$\Rightarrow L_j = 29.56\ m$

Ex. 7.2 $b = 6m$; $s = 2$; $Q = 120\ m^3/s$; $h_1 = 1m$

$$Fr = \frac{V}{\sqrt{gD}} = \frac{15}{\sqrt{9.81 \times 0.8}} = 5.35 > 1$$

$$F_1 = \frac{Q^2}{gA_1} + \bar{z}_1 A_1 = \frac{120^2}{9.81 \times 8} + 0.46 \times 8$$

$$= 187$$

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

$$D = \frac{A}{B} = \frac{8}{10} = 0.8\ m$$

$$A = bh + sh^2$$

$$= 6 \times 1 + 2 \times 1^2 = 8\ m^2$$

$$B = b + 2sh = 6 + 2 \times 2 = 10$$

$$V = \frac{Q}{A} = \frac{120}{8} = 15\ m/s$$

$$z_1 = \frac{h}{6}\left(\frac{3b + 2sh}{b + sh}\right)$$

$$= \frac{1}{6}\left(\frac{3 \times 6 + 2 \times 2}{6 + 2}\right) = 0.46\ m$$

h	$\bar{z}_2$	A_2	F_2
4	1.62	56	116.88
5	1.98	80	176.68
5.5	2.16	93.5	217.37
5.2	2.05	85.28	192.07
5.18	2.04	84.74	190.5
5.165	2.04	84.34	189.3
5.15	2.03	83.95	188.1
5.135	2.03	83.55	187

Ex. 7.3

$$E_1 = h_1 + \frac{v_1^2}{2g} = 1 + \frac{15^2}{2 \times 9.81} = 12.5$$

$$E_2 = h_2 + \frac{v_2^2}{2g} = 5.135 + \frac{1.44^2}{2 \times 9.81} = 5.24$$

$$\therefore 1 - \frac{E_2}{E_1} = 0.58$$

$$v_2 = \frac{Q}{A_2} = \frac{120}{6 \times 5.135 + 2 \times 5.135^2}$$

$$= 1.44 \text{ m/s}$$

Computation of gradually varied flow profile

Computation via integration — graphically, or ...

L09

05/04

Chapter 6

L10 07/04

Section B: 40 mnks → nafid sir
80 → ma'am
compulsory → ma'am
} mix

$$Fr_1 = \frac{V_1}{\sqrt{gh_1}}$$

103 page design by method of lance
angle be given

Ex. 5.4 (triangular)

Sketch (P116)

Ex. 6.1, 6.2

Euler method

P143 math

Theory not from where CT conducted

Stilling basin

Chute blocks (▽)

Sill, dentated on solid

~~Ex.~~ Ex. 7.5

Rough / Final

24/04

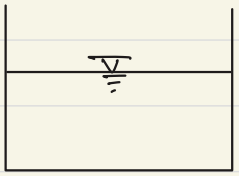
Chapter 5 Design of channels

Design of 3 channels:

(i) Rigid boundary → No silting, no scouring
(ii) Mobile boundary → Scours
(iii) Alluvial → silting & scouring

In design, maintain F_r → 0.3 to 0.4

Freeboard →



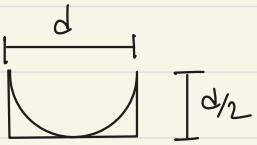
Freeboard → 5% – 30% of depth of flow
F_b

Q (m^3/s) →	< 0.75	0.75 – 1.5	1.5 – 85	> 85
F_b (m)	0.45	0.60	0.75	0.90

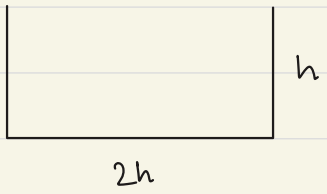
Minimum permissible vel (non-silting) → 2.5 ft/s (0.75 m/s)
Maximum " " (non-scouring) → 2 m/s

Best hydraulic section → minimum wetted perimeter (min linings)
maximum discharge

→ Semi-circle
→ Rect → B = 2h
→ Triangle → S = 1
→ Trapezoidal → S = 1/√3



Rectangular → $b = 2h$



$A = 2h^2$

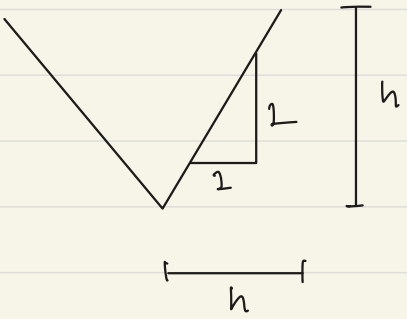
$B = 2h$

$P = 4h$

$R = A/P = 2h^2/4h = \frac{1}{2}h$

$D = A/B = h$

Triangular → $S = 1$



$A = 2 \cdot \frac{1}{2} h^2 = h^2$

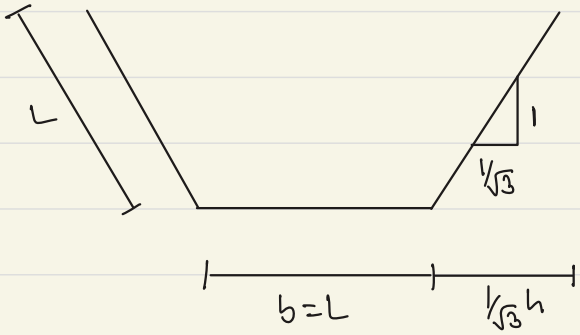
$B = 2h$

$P = 2\sqrt{2}\,h$

$R = A/P = h^2/2\sqrt{2}h = \frac{1}{2\sqrt{2}}h$

$D = A/B = h^2/2h = \frac{1}{2}h$

Trapezoidal → $S = 1/\sqrt{3}$



$A = bh + sh^2$

$= \frac{2}{\sqrt{3}}h^2 + \frac{1}{\sqrt{3}}h^2$

$= \sqrt{3}\,h^2$

$B = \frac{2}{\sqrt{3}}h + 2\frac{1}{\sqrt{3}}h = \frac{4}{\sqrt{3}}h$

$P = \frac{2}{\sqrt{3}}h \times 3 = 2\sqrt{3}\,h$

$R = A/P = \frac{1}{2}h$

$D = A/B = \frac{\sqrt{3}h^2}{4/\sqrt{3}h} = \frac{3}{4}h$

$L = h\sqrt{1+(1/\sqrt{3})^2}$

$= \frac{2}{\sqrt{3}}h$

Ex. 5.1 Best hydraulic sec ½ of sqr → rect

$A = bh \Rightarrow b = A/h$

$P = b + 2h = A/h + 2h$

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

For min P, $\frac{dP}{dh} = 0$

$\Rightarrow -\frac{A}{h^2} = -2$

$\Rightarrow A = 2h^2$

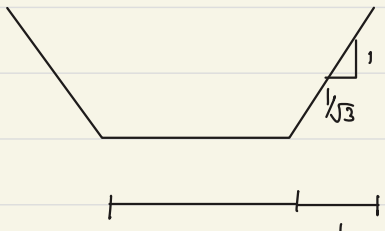
$\Rightarrow bh = 2h^2 \Rightarrow b = 2h$

Ex. 5.3 $Q = 20\ m^3/s$; $S_0 = 0.001$; $n = 0.025$

$$AR^{2/3} = \frac{nQ}{\sqrt{S_0}} = \frac{0.025 \times 20}{\sqrt{0.001}} = 15.81$$

$A = bh + sh^2$

$= \frac{2}{\sqrt{3}}h^2 + \frac{1}{\sqrt{3}}h^2 = \sqrt{3}h^2$



$P = 3 \times \frac{2}{\sqrt{3}}h = 2\sqrt{3}h$

$L = h\sqrt{1 + 1/3}$

$= \frac{2}{\sqrt{3}}h$

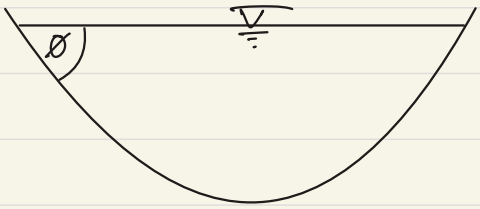
$\therefore (\sqrt{3}h^2)\left(\frac{\sqrt{3}h^2}{2\sqrt{3}h}\right)^{2/3} = 15.81$

$\Rightarrow h = 2.73\ m$ (freeboard = 0.77m)

$V = \frac{Q}{A} = \frac{20}{\sqrt{3} \times 2.73^2} = 1.55\ m/s$ (> 0.75 m/s)

$F_R = \frac{V}{\sqrt{gD}} = \frac{1.55}{\sqrt{9.81 \times \frac{\sqrt{3} \times 2.73^2}{(2\sqrt{3} \times 2.73) \times 2}}} = 0.35$ (0.3 ~ 0.4)

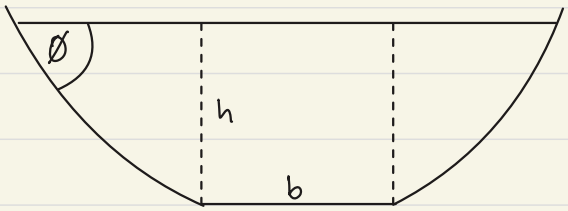
Practical rigid-boundary sections



$Q < 55\ m^3/s$

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

$P = 2h(\phi + \cot\phi)$

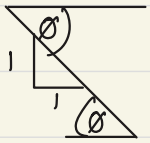


$Q > 55\ m^3/s$

$A = bh + h^2(\phi + \cot\phi)$

$P = b + 2h(\phi + \cot\phi)$

Ex. 5.4 $S_o = 0.00028$; $s = 1$; $n = 0.013$;



$\phi = \tan^{-1}(1/1)$

$= 0.785$

(a) $Q = 35\ m^3/s$ → triangular, rounded

$A = h^2(\phi + \cot\phi) = 1.785h^2$

$P = 2h(\phi + \cot\phi) = 3.57h$

$$AR^{2/3} = \frac{nQ}{\sqrt{S_o}} = A^{5/3}\frac{1}{P^{2/3}}$$

$$\Rightarrow \frac{0.013 \times 35}{\sqrt{0.00028}} = (1.785h^2)^{5/3}\frac{1}{(3.57h)^{2/3}}$$

$\Rightarrow h = 3.3\ m$

(b) $Q = 100\ m^3/s \rightarrow$ Trapezoidal

Using limit $U = 2\ m/s$

$Q = AU \Rightarrow A = Q/U = \frac{100}{2} = 50\ m^2$

$Q = \frac{1}{n} A R^{2/3} \sqrt{S_0} \Rightarrow 100 = \frac{1}{0.013} \times 50 \times R^{2/3} \sqrt{0.00028}$

$\Rightarrow R = 1.94 = A/P$

$\Rightarrow P = 50/1.94 = 25.77$

Now, $A = bh + h^2(\phi + \cot\phi)$

$\Rightarrow 50 = bh + h^2 1.785$ —— (i)

$P = b + 2h(\phi + \cot\phi)$

$\Rightarrow 25.77 = b + 2h \times 1.785$ —— (ii)

(i) − (ii)$\times h \Rightarrow bh + 1.785h^2 - bh - 3.57h^2 = 50 - 25.77h$

$\Rightarrow -1.785h^2 + 25.77h - 50 = 0$

$\Rightarrow h = 12.13,\ 2.31\ m$

when $h = 12.13\ m$, $b = -17.59\ m$

✓ $h = 2.31\ m$, $b = 17.52\ m$

Ex 5.5 Trapezoidal

$n = 0.013$

$S_0 = 0.00028$

$Q = 100\ m^3/s$

(a) $b = 6m, \quad s = 1$

$$AR^{2/3} = \frac{nQ}{\sqrt{S_0}}$$

$$\Rightarrow (bh + sh^2)^{5/3} \times \left(\frac{1}{b + 2h\sqrt{1+s^2}}\right)^{2/3} = \frac{0.013 \times 100}{\sqrt{0.00028}}$$

$$\Rightarrow (6h + h^2)^{5/3} \times \left(\frac{1}{6 + 2h\sqrt{2}}\right)^{2/3} = 77.69$$

$$\Rightarrow h = 4.23\ m$$

(b) Considering best hydraulic section, $s = 1$

$$\left.\begin{aligned} R &= 0.5h \\ A &= h^2(2\sqrt{1+s^2} - s) \\ b &= 2h(\sqrt{1+s^2} - s) \end{aligned}\right\}$$ memo; can be derived through $\frac{dP}{dh} = 0$

$$AR^{2/3} = \frac{nQ}{\sqrt{S_0}}$$

$$\Rightarrow \{h^2(2\sqrt{1+s^2} - s)\}\{0.5h\}^{2/3} = 77.69$$

$$\Rightarrow \{h^2(2\sqrt{2} - 1)\}\{0.5h\}^{2/3} = 77.69$$

$$\Rightarrow h = 4.85$$

$$b = 2h(\sqrt{1+s^2} - s) = 2 \times 4.85(\sqrt{2} - 1) = 4.02\ m$$

(c) $S = 2$; $b = 8.23\ m$

$$AR^{2/3} = 77.69$$

$$\Rightarrow (bh + sh^2)^{5/3} \times \frac{1}{(b + 2h\sqrt{1+s^2})^{2/3}} = 77.69$$

$$\Rightarrow (8.23h + h^2)^{5/3} \times \frac{1}{(8.23 + 2h\times\sqrt{5})^{2/3}} = 77.69$$

$$\Rightarrow h = 3.68\ m$$

Erodible channel that do not silt but scour (shear or tractive force method):

Channel scours when $\tau_0 > \tau_c$

max shear stress is more on bed than sides

find out shear stress in terms of γhs. from graph

Shear stress ratio:

Shear on side $\rightarrow \tau_s$

Shear on bed $\rightarrow \tau_b$

$$K = \frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\sin^2\phi}{\sin^2\psi}}$$; ψ = angle of repose

find from graph

Permissible $\tau_{b,max} = 0.40\, d_{75}$ (d_{75} in inch, $\rightarrow$ lb/ft^2)

Design $\Rightarrow \psi \rightarrow K \rightarrow \tau_b \rightarrow \tau_s \rightarrow \tau_{s,max} \rightarrow h_n$ [Assume $b/h_n = 4$, $S = 2$]

Ex 5.6 $S_o = 0.001$; $Q = 20\ m^3/s$

Moderately rounded coarse non-cohesive

$d_{75} = 2.5\ cm = 0.98\ in$

$n = 0.025$

Assume: $b/h = 4$; $S = 2$; $\phi = \tan^{-1} 1/2 = 26.57°$

$$\tau_s = 0.75 \gamma h_n S_o = 7.36 h_n$$

$\psi = 33°$

$$K = \sqrt{1 - \frac{\sin^2\phi}{\sin^2\psi}} = 0.571$$

$$\tau_{b,max} = 0.4 d_{75} = 0.4 \times 0.98 = 0.392\ lb/ft^2$$

$$= 18.78\ N/m^2$$

$$\tau_{s,max} = 0.571 \times 18.78 = 10.72\ Pa$$

$$\therefore 7.36 h_n = 10.72 \Rightarrow h_n = 1.46\ m$$

$$b = 4 \times 1.46 = 5.84\ m$$

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

$$= \frac{1}{0.025} \times (5.84 \times 1.46 + 2 \times 1.46^2)^{5/3} \times \frac{1}{(5.84 + 2 \times 1.46\sqrt{5})^{2/3}} \times \sqrt{0.001}$$

$$= 16.54\ m^3/s < 20\ m^3/s$$

$\therefore$ Suitable b_m: $AR^{2/3} = \frac{nQ}{\sqrt{S_o}} = 15.81$

$$\Rightarrow (bh + sh^2)^{5/3} \frac{1}{(b + 2h\sqrt{1+s^2})^{2/3}} = 15.81;\quad h = 1.46\ m,\ s = 2$$

$$\Rightarrow b = 7.36\ m$$

$\therefore h_n = 1.46\,m;\quad b = 7.36\,m;\quad Q = 20\ m^3/s$

$\tau_b = 0.97\,\gamma\,h_n S_0 = 13.89\ N/m^2 \;<\; 18\ N/m^2$

Ex 5.6 (RE): $S_0 = 0.001;\quad Q = 20\ m^3/s$

Moderately rounded coarse non-cohesive

$d_{75} = 2.5\ cm = 0.98\ in$

$n = 0.025$

Permissible: $\tau_b = 0.4\,d_{75} = 0.4 \times 0.98 = 0.392\ lb/ft^2$

$= 18.78\ Pa$

$\psi = 33^\circ$

$\therefore K = \frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\sin^2\phi}{\sin^2\psi}}$

$= \sqrt{1 - \frac{\sin^2 26.57}{\sin^2 33^\circ}}$

$= 0.571$

Let $b/h = 4$

$s = 2$

$\therefore \phi = \tan^{-1} 1/2$

$= 26.57^\circ$

$\therefore \tau_s = 0.571 \times 18.78 = 10.72\ Pa$

Actual: $\tau_s = 0.75\,\gamma\,h_n S_0 = 0.75 \times 9810 \times 0.001\,h_n = 7.36\,h_n$

$\therefore 7.36\,h_n = 10.72 \Rightarrow h_n = 1.46\ m$

$b = 4h = 5.84\ m$

$\therefore A = bh + sh^2 = 12.78\ m^2$

$P = b + 2h\sqrt{1+s^2} = 12.37\ m$

$$\therefore Q = \frac{1}{n} A R^{2/3} \sqrt{S_0}$$

$$= \frac{1}{0.025} \times 12.78 \times \left(\frac{12.78}{12.37}\right)^{2/3} \times \sqrt{0.001} = 16.52 \ m^3/s \quad (< 20 \ m^3/s)$$

Try change param b : $AR^{2/3} = \frac{nQ}{\sqrt{S_0}}$

$$\Rightarrow (bh + sh^2)^{5/3} \times \frac{1}{(b + 2h\sqrt{1+s^2})^{2/3}} = \frac{0.025 \times 20}{\sqrt{0.001}}$$

$$\Rightarrow (1.466 + 2 \times 1.46^2)^{5/3} \times \frac{1}{(b + 2 \times 1.46\sqrt{1+2^2})^{2/3}} = 15.81$$

$$\Rightarrow b = 7.36 \ m$$

$$\tau_b = 0.97 \gamma h_n S_0 = 0.97 \times 9810 \times 1.46 \times 0.001 = 13.89 < 18.78 \ Pa$$

Alluvial channel: Regime Approach

Ex 5.7 $Q = 10\ m^3/s$; $d = 1\ mm$

$$P = 4.75\sqrt{Q} = 15.02\ m$$

$$f_s = 1.76\sqrt{d} = 1.76$$

$$R = 0.47\left(\frac{Q}{f_s}\right)^{1/3} = 0.84\ m$$

$$S_0 = \frac{f_s^{5/3}}{3340\,Q^{1/6}} = 0.00052$$

Now, $A = RP = 0.84 \times 15.02 = 12.62\ m^2$

Also, $A = bh + sh^2 = bh + 0.5h^2$ —(I) $[s = 1/2]$

Again, $P = b + 2h\sqrt{1+s^2} = b + 2h\sqrt{1.25}$ —(II)

Now, (I) − (II)×h $\Rightarrow bh + 0.5h^2 - bh - 2h^2\sqrt{1.25} = 12.62 - 15.02h$

$\Rightarrow -1.736h^2 + 15.02h - 12.62 = 0$

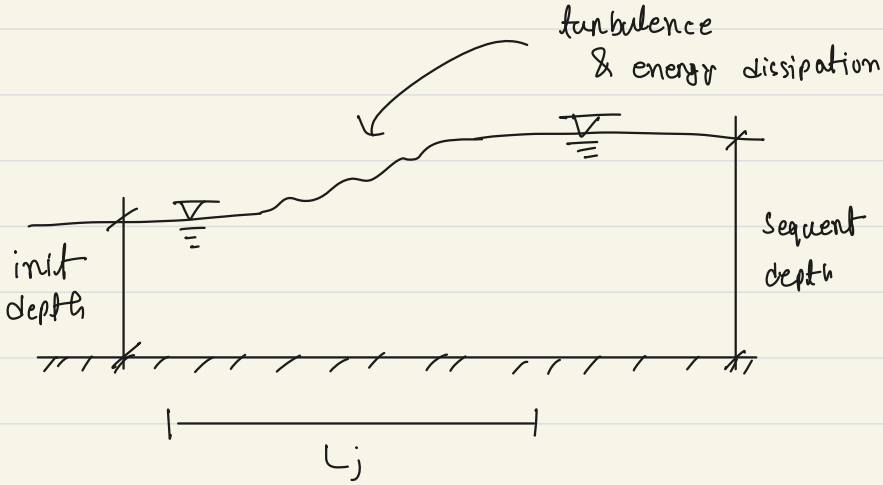
$\therefore h = 7.71\ m,\ 0.94\ m$

$b = -2.22\ m,\ 12.96\ m$

Chapter 7: Hydraulic jump

Supercritical flow $\xrightarrow{\text{jump}}$ subcritical flow

Two controls (one from u/s and another from d/s) operates on the same reach

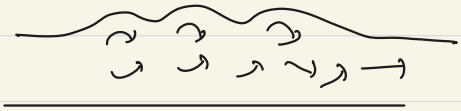


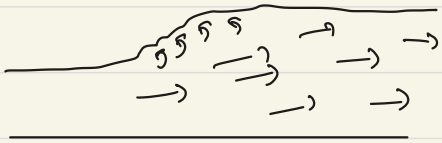
Uses:

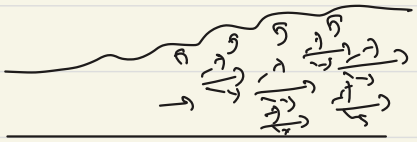
(i) Energy dissipation → prevent scouring d/s
(ii) Increase depth → for irrigation & water distribution
(iii) Increase discharge → under sluice, to repel tailwater & ensure free flow
(iv) Reduce uplift pressure by increasing wt on apron
(v) Chemical mixing
(vi) Removal of air pockets on supply pipes
(vii) Aeration on supply lines

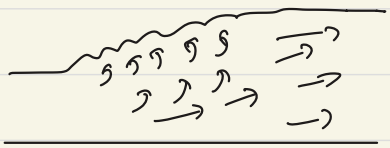
Types of jump:

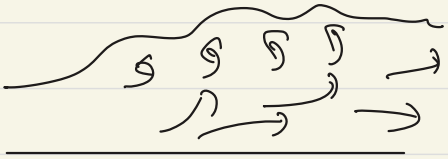
u/s F_D	Type
1 – 1.7	Undular
1.7 – 2.5	weak
2.5 – 4.5	Oscillating
4.5 – 9	Steady
> 9	Strong



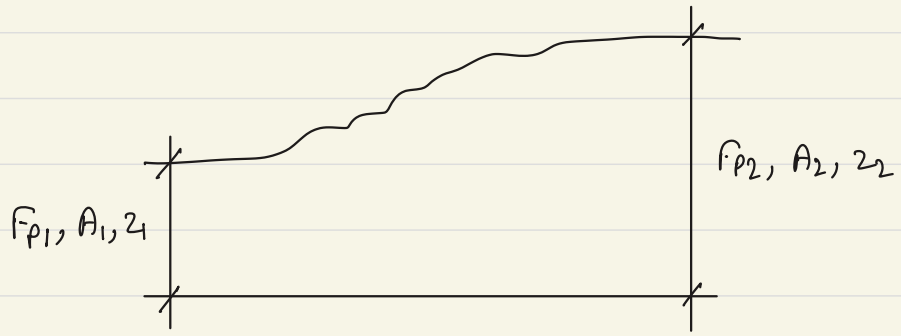








Sequent depth (Rect. channel, horizontal)



Momentum eqn: $\rho Q(\beta_2 v_2 - \beta_1 v_1) = F_{P_1} - F_{P_2} + W\sin\theta - F_f$

$\Rightarrow \rho Q\left(\frac{Q_2}{A_2} - \frac{Q_1}{A_1}\right) = \rho g \bar{z}_1 A_1 - \rho g \bar{z}_2 A_2$

$\Rightarrow \frac{Q_2^2}{A_2} + g A_2 \bar{z}_2 = \frac{Q_1^2}{A_1} + g A_1 \bar{z}_1$

$\Rightarrow \frac{Q_2^2}{gA_2} + A_2\bar{z}_2 = \frac{Q_1^2}{gA_1} + A_1\bar{z}_1$ → specific force eqn

Condition for hydraulic jump → $\Rightarrow F_2 = F_1$; $F = \frac{Q^2}{gA} + A\bar{z}$

$\frac{Q^2}{gA}$ → momentum force

$A\bar{z}$ → pressure force

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

Length of jump: Hon. distance from face of jump to a point immediately d/s of roller

$$\frac{L_j}{h_1} = 9.75\,(Fr_1 - 1)^{1.01}$$

Energy loss:

$$h_L = E_1 - E_2 = \frac{(h_1 - h_2)^3}{4 h_1 h_2}$$ [for rect]

Relative loss:

$$\frac{h_L}{E_1} = 1 - \frac{E_2}{E_1}$$ ← efficiency

[$\frac{E_2}{E_1} = \ldots$; should be given]

Height of jump: $h_j = h_2 - h_1$

$$\frac{h_j}{h_1} = \frac{1}{2}\left(\sqrt{1 + 8 Fr_1^2} - 3\right)$$

Relative ht of jump → $\frac{h_j}{E_1} = \frac{\sqrt{1 + 8 Fr_1^2} - 3}{2 + Fr_1^2}$

Ex. 7.1 Rect; $b = 6m$; $h_1 = 0.52m$; $V_1 = 15.2\ m/s$;

(i) $F_{r_1} = \frac{V_1}{\sqrt{gD_1}} = \frac{15.2}{\sqrt{9.81 \times 0.52}} = 6.73$ (4.5 – 9)

$\therefore$ Steady jump

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

$\Rightarrow h_2 = \frac{1}{2}\left(\sqrt{1+8\times 6.73^2} - 1\right) \times 0.52$ m

$= 4.7m$

(iii) $h_L = \frac{(h_2 - h_1)^3}{4h_1 h_2} = \frac{(4.70 - 0.52)^3}{4 \times 4.70 \times 0.52} = 7.47m$

Dissipation $= \gamma Q h_L = 9810 \times (15.2 \times 0.52 \times 6) \times 7.47$

$= 3475264\ N\frac{m}{s}$ (watt)

$\therefore HP = \frac{3475264}{745.7} = 4660\ HP$

(iv) $E_1 = h_1 + \frac{u_1^2}{2g} = 0.52 + \frac{15.2^2}{2 \times 9.81} = 12.3\ m$

$E_2 = E_1 - h_L = 12.3 - 7.47 = 4.83$

$\therefore$ Efficiency $= \frac{E_2}{E_1} = 0.39 \rightarrow 39\%$

(v) $\frac{h_j}{E_1} = \frac{h_2 - h_1}{E_1} = \frac{4.7 - 0.52}{12.3} = 0.3398 = 33.98\%$

(vi) $\frac{L_j}{h_1} = 9.75(F_{r_1} - 1)^{1.01}$

$\Rightarrow L_j = 9.75(6.73 - 1)^{1.01} \times 0.52 = 29.56\ m$

Jumps in horizontal non-rectangular

$$F_1 = F_2$$

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

Section	$\bar{z}$
Rect.	$h/2$
Triangular	$h/3$
Trapezoidal	$\frac{h}{6}\left[\frac{3b+2sh}{b+sh}\right]$
Parabolic	$2h/5$

Ex. 7.2 Trapezoidal; $b = 6\,m$, $s = 2$, $Q = 120\ m^3/s$

$h_1 = 1m$

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

$$= 187.1$$

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

$$A_2 = bh + sh^2 = 6h_2 + 2h_2^2$$

$$z_2 = \frac{h_2}{6}\left[\frac{3\times 6 + 2\times 2h_2}{6+2h_2}\right]$$

$$= \frac{h_2}{6}\left[\frac{18+4h_2}{6+2h_2}\right]$$

$$A_1 = bh + sh^2$$

$$= 6\times 1 + 2\times 1^2 = 8\,m^2$$

$$\bar{z} = \frac{h}{6}\left[\frac{3b+2sh}{b+sh}\right]$$

$$= \frac{1}{6}\left[\frac{3\times 6 + 2\times 2\times 1}{6+2}\right]$$

$$= 0.45\ m$$

Trial:

$h_2 > h_1$	A_2	F_2
2	20	90.73
3	36	85.8
5	80	176.7
5.2	85.3	192.1
5.15	83.95	188.1
5.14	83.7	187.33

Ex 7.3

$$E_1 = h_1 + \frac{Q^2}{2g A_1^2} = 1 + \frac{120^2}{2\times 9.81\times 8^2} = 12.47 \text{ m}$$

$$E_2 = h_2 + \frac{Q^2}{2g A_2^2} = 5.14 + \frac{120^2}{2\times 9.81\times 83.7^2} = 5.24 \text{ m}$$

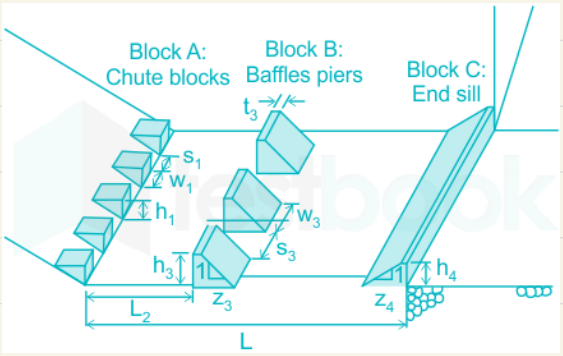
$$\therefore \text{Relative energy loss} = \frac{h_L}{E} = 1 - \frac{E_2}{E_1} = 1 - \frac{5.24}{12.47} = 0.58 - 58\%$$

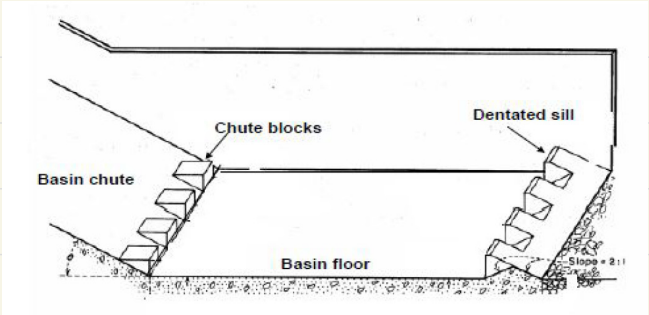
Stilling basin

A short length of paved channel at the end of spillway that is used for energy dissipation during hydraulic jump.

Special appurtenances:

Chute block
Sill, dentated
Baffle piers





Design : USBR Basin II

for $F_{r_1} \geq 4.5$

$U = \geq 18$ m/s

Fall ≤ 60 m

$Q \leq 46 \ (m^3/s)/m$

Consists of chute blocks & sill dentated

Chute block: spacing, width, ht $= h_1$

wall space $= 0.5 h_1$

Sill, dentated: spacing, width $= 0.15 h_2$

ht $= 0.2 h_2$

top thickness $= 0.02 h_2$

Ex 7.5 $Q_{design} = 15870\ m^3/s$

$h_{tw} = 17.26\ m$

$b = 227.1\ m$

$el = 0.00\ m$

$V_1 = 24.70\ m/s$

$Q = AV \Rightarrow h_1 = \frac{Q}{bV} = \frac{15870}{227.1 \times 24.7} = 2.83\ m$

$Fr_1 = \frac{V}{\sqrt{gD}} = \frac{24.7}{\sqrt{9.81 \times 2.83}} = 4.69$

Since $V_1 > 18\ m/s$ & $Fr_1 \geq 4.5$; USBR II design to be used

$\frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1+8Fr_1^2} - 1\right) = 17.41\ m > (h_{tw} = 17.26\ m)$

$\therefore$ basin floor to be lowered $= (1.05 \times 17.41 - 17.26)$

$= 1.02\ m$

Length of basin: $\frac{L}{h_2} = 3.8$

$\Rightarrow L = 3.8 \times 17.41 = 66.16\ m$

Chute block: ht, width, spacing $= h_1 = 2.83\ m$

Sill, dentated: $ht = 0.2 h_2 = 3.48\ m$

width, spacing $= 0.15 h_2 = 2.61\ m$

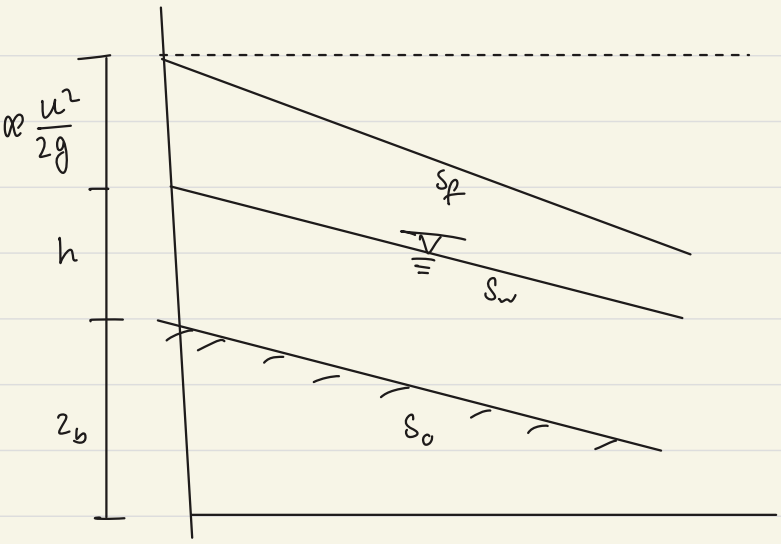
Chapter 6: Gradually varied flow

$$H = z_b + h + \alpha \frac{v^2}{2g}$$

$$\Rightarrow \frac{dH}{dx} = \frac{dz_b}{dx} + \frac{dh}{dx} + \frac{d}{dx}\frac{\alpha v^2}{2g}$$

Here, $\frac{dH}{dx} = -S_f$

$$\frac{dz_b}{dx} = -S_0$$



$$\frac{d}{dx}\frac{\alpha v^2}{2g} = \frac{d}{dx}\frac{\alpha Q^2}{2gA^2} = \frac{\alpha}{2g}(-2)\frac{Q^2}{A^3}\frac{dA}{dh}\frac{dh}{dx}$$

$$= -\frac{\alpha}{g}\frac{v^2 B}{BD}\frac{dh}{dx}$$

$$= -Fr^2\frac{dh}{dx}$$

$$\therefore \frac{dh}{dx} = \frac{dH}{dx} - \frac{dz_b}{dx} - \frac{d}{dx}\alpha\frac{v^2}{2g}$$

$$= -S_f + S_0 + Fr^2\frac{dh}{dx}$$

$$\Rightarrow \frac{dh}{dx}(1 - Fr^2) = S_0 - S_f$$

$$\Rightarrow \frac{dh}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$ ← dynamic eqn of gradually varied flow

- $> 0 \rightarrow$ backwater curve
- $< 0 \rightarrow$ drawdown curve

$$\frac{dh}{dx} = \frac{S_0 - S_f}{1 - Fr^2} = S_0 \frac{1 - \frac{S_f}{S_0}}{1 - Fr^2}$$

$$S_0 = \frac{Q^2}{K_n^2} \; ; \quad S_f = \frac{Q^2}{K^2}$$

$$\Rightarrow \frac{S_f}{S_0} = \frac{K_n^2}{K^2}$$

And, $$Z = A\sqrt{D} \; ; \quad Z_c = \frac{Q}{\sqrt{g/\alpha}}$$

$$\Rightarrow Z^2 = A^2 D \; ; \quad Z_c^2 = \frac{\alpha Q^2}{g}$$

$$\therefore \frac{Z_c^2}{Z^2} = \frac{\alpha Q^2}{g A^2 D} = \frac{\alpha U^2}{g D} = Fr^2$$

$$\therefore \frac{dh}{dx} = S_0 \frac{1 - \frac{S_f}{S_0}}{1 - Fr^2} = S_0 \frac{1 - (K_n/K)^2}{1 - (Z_c/Z)^2}$$

Again, $$Z^2 = C_1 h^m \; ; \quad Z_c^2 = C_1 h_c^m$$

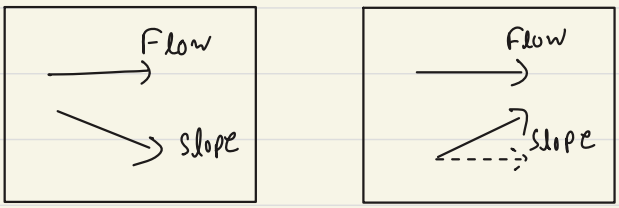
$$K^2 = C_2 h^N \; ; \quad K_n^2 = C_2 h_n^N$$

$$\therefore \frac{K_n^2}{K^2} = \left(\frac{h_n}{h}\right)^N \; ; \quad \frac{Z_c^2}{Z^2} = \left(\frac{h_c}{h}\right)^m$$

$$\therefore \frac{dh}{dx} = S_0 \frac{1 - (h_n/h)^N}{1 - (h_c/h)^M}$$

Classification of flow profile of gradually varied flow

Types of bottom slope:



Positive Negative

Positive: (i) Mild slope → $S_0 < S_c$ → $h_n > h_c$ [M]

(ii) Critical slope → $S_0 = S_c$ → $h_n = h_c$ [C]

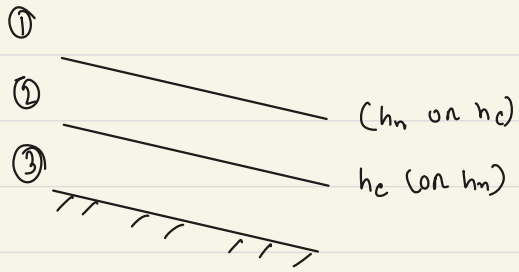
(iii) Steep slope → $S_0 > S_c$ → $h_n < h_c$ [S]

Negative: (i) Horizontal → $S_0 = 0$ ← $h_n \to \infty$ [H]

(ii) Adverse → $S_0 < 0$ ← $h_n \to$ imaginary [A]

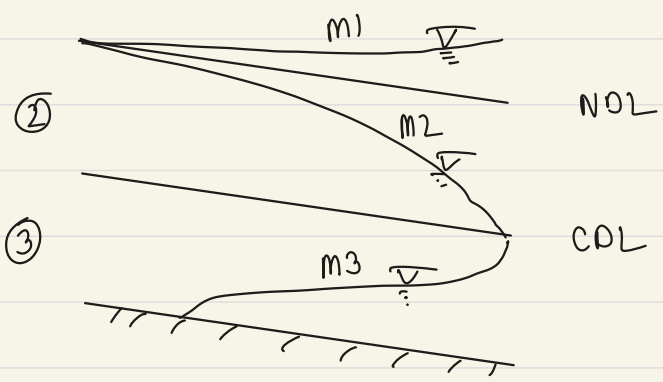
not physically possible

Zoning:

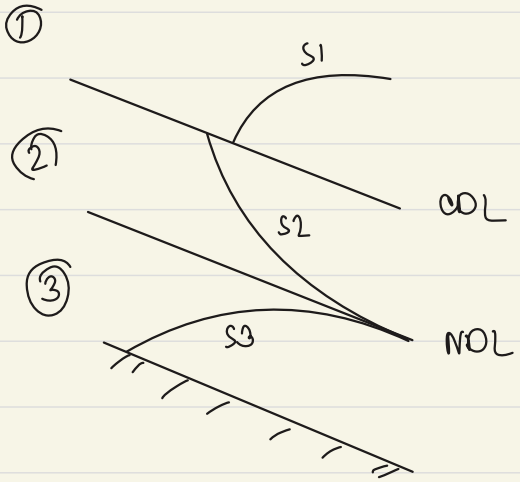


Naming: M1, M2, M3, C1, C2, ...

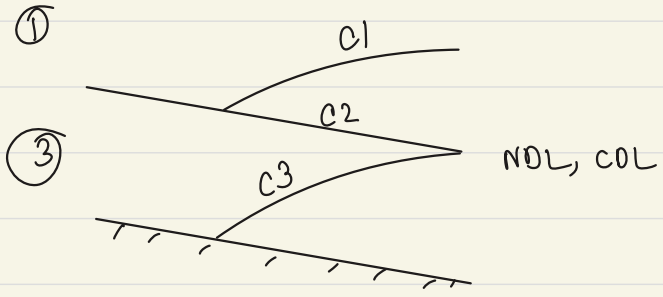
Mild : ①



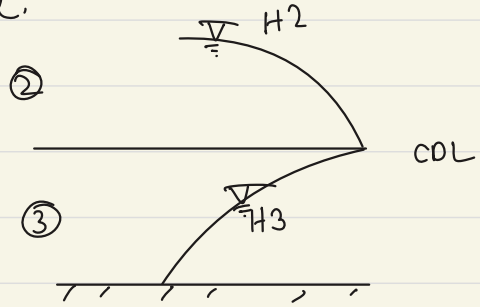
Steep :



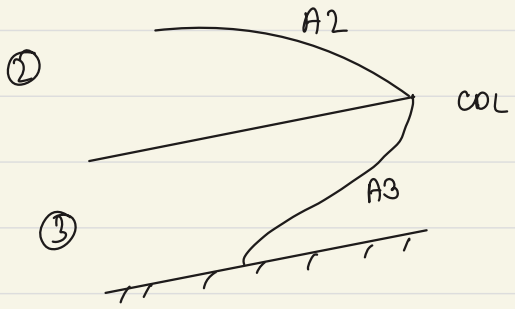
Critical



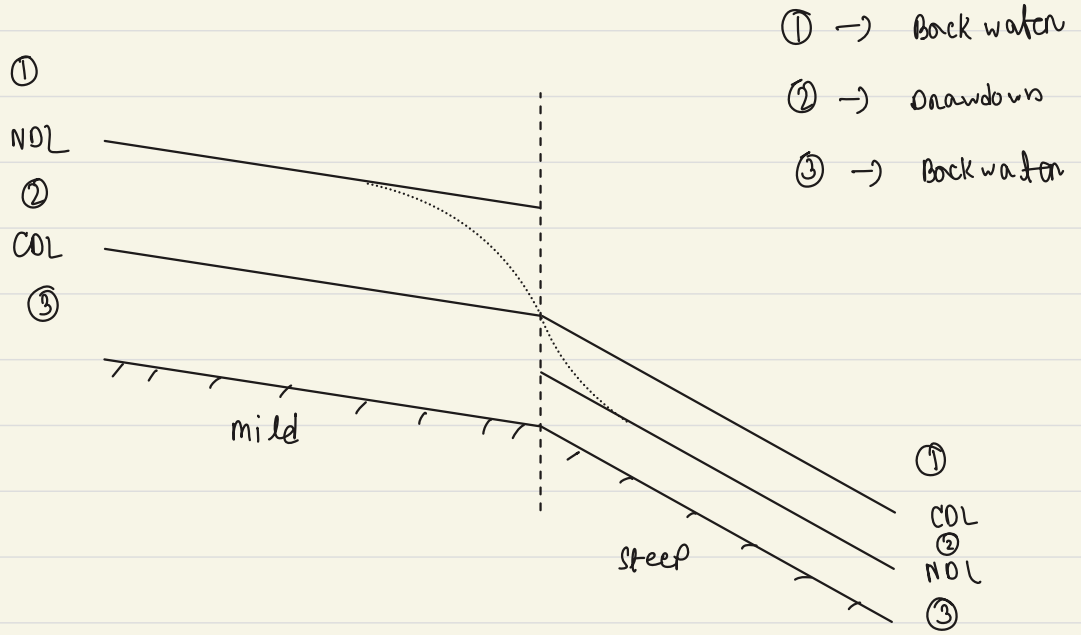
Horizontal:

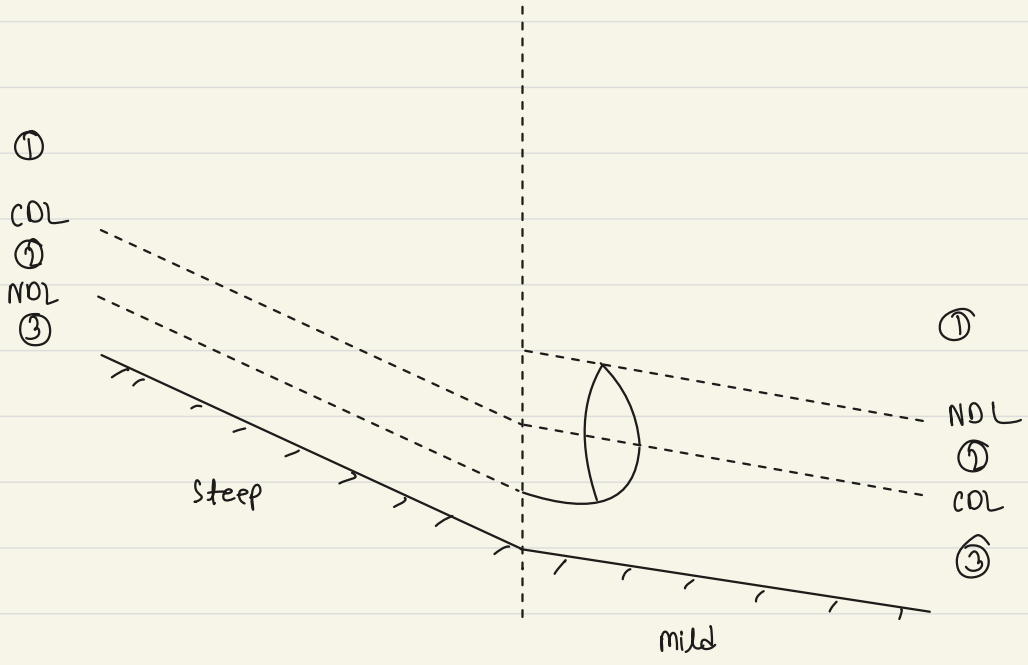


Abrupt:



Flow profile in serial arrangement





Ex. 6.1 Trapezoidal; $b = 6m$; $n = 0.025$; $s = 2$; $S_0 = 0.001$

$Q = 28\ m^3/s$; $h_{A-A} = 1.3m$

Normal depth:

$$AR^{2/3} = \frac{nQ}{\sqrt{S_0}}$$

$$\Rightarrow (bh+sh^2)^{5/3} \frac{1}{(b+2h\sqrt{1+s^2})^{4/3}} = \frac{0.025 \times 28}{\sqrt{0.001}}$$

$$\Rightarrow (6h+2h^2)^{5/3} \times \frac{1}{(6+2h\sqrt{5})^{2/3}} = 22.14$$

$$\Rightarrow h = 1.9\ m$$

Critical depth:

$$z_c = \frac{Q}{\sqrt{g/\alpha}} = \frac{28}{\sqrt{9.81/1}} = 8.94$$

$$z = A\sqrt{D} = (bh+sh^2)^{1.5} \times \frac{1}{b+2sh} = z_c = 8.94$$

$$\Rightarrow (6h+2h^2)^{1.5} \times \frac{1}{(6+4h)^{0.5}} = 8.94$$

$$\Rightarrow h = 1.14\ m$$

(i) $h_n > h_c \rightarrow$ mild

(ii) $h_{A-A} < h_n$ & $h_{A-A} > h_c \rightarrow$ M2

(iii) M2 $\rightarrow$ drawdown

$\therefore$ 1.5 m $\rightarrow$ 1.3 m; B-B at u/s of A-A

B-B A-A

Ex. 6.2 Rect. $b = 10\,m$, $\alpha = 1.10$, $n = 0.025$, $Q = 35\ m^3/s$

$S_0 = 0.0040,\ 0.0065,\ 0.0090$

Critical depth:

$$h_c = \sqrt[3]{\frac{\alpha Q^2}{g b^2}} = \sqrt[3]{\frac{1.1 \times 35^2}{9.81 \times 10^2}} = 1.11\ m$$

Critical slope:

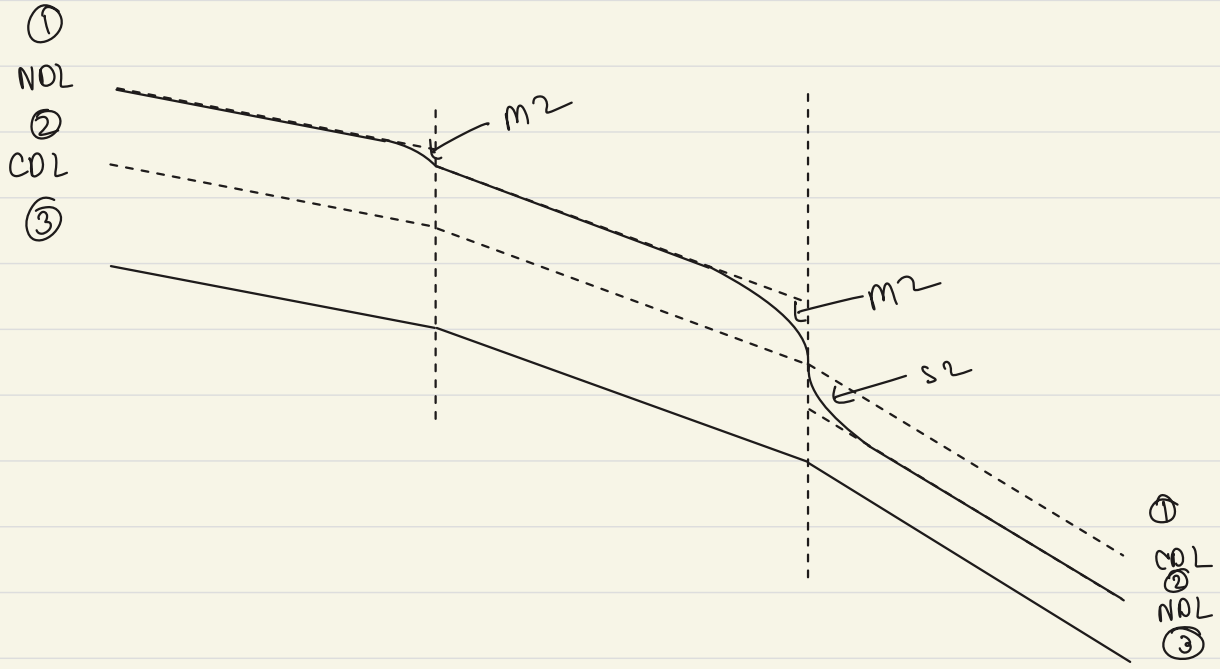
$$A_c R_c^{2/3} = \frac{nQ}{\sqrt{S_c}}$$

$$\Rightarrow (b h_c)^{5/3} \times \frac{1}{(b+2h_c)^{2/3}} = \frac{0.025 \times 35}{\sqrt{S_c}}$$

$$\Rightarrow (10 \times 1.11)^{5/3} \times \frac{1}{(10+2\times 1.11)^{2/3}} = \frac{0.875}{\sqrt{S_c}}$$

$$\Rightarrow 0.0071$$

$\therefore$ Mild $\rightarrow$ Mild steeper $\rightarrow$ Steep



Direct int. method:

Ex 6.3 $C = 47\sqrt{m}/s$; $S_0 = 0.0001$; $q = 2\ m^2/s$

rise = 0.5m

$$h_n = \sqrt[3]{\frac{q^2}{C^2 S_0}} = \sqrt[3]{\frac{2^2}{47^2 \times 0.0001}} = 2.63\ m$$

$$h_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{2^2}{9.81}} = 0.74\ m$$

$h_1 = h_n + 0.5 = 3.13\ m$; $u_1 = h_1/h_n = 1.19$; $u_2 = \frac{h_2}{h_n} = 1.10$ ← 2.9

$$\phi_1 = \frac{1}{6}\ln\frac{u^2+u+1}{(u-1)^2} - \frac{1}{\sqrt{3}}\tan^{-1}\frac{\sqrt{3}}{2u+1}$$

take more digits

$= 0.494$

$\phi_2 = \cdots = 0.681$ ← 0.673

$$\therefore L = \frac{h_n}{S_0}\left[(u_2-u_1) - \left(1 - \frac{h_c^3}{h_n^3}\right)(\phi_2-\phi_1)\right]$$

$= -7176\ m$

Ex. 6.7 Depth of flow 100 m u/s

Trapezoidal; $b = 6m$, $S = 2$, $S_0 = 0.0025$, $Q = 30\ m^3/s$

$\alpha = 1.12$, $n = 0.025$

$h_j = 2.5\ m$

Euler method: $\frac{d}{dx}(h_j) = \frac{S_0 - S_f}{1 - Fn^2}$

$S_0 = 0.0025$

S_f: $AR^{2/3} = \frac{nQ}{\sqrt{S_f}}$

$\Rightarrow (27.5)^{5/3} \times \frac{1}{(17.18)^{2/3}} \frac{0.025 \times 30}{\sqrt{S_f}}$

$\Rightarrow S_f = 0.000397$

$A = bh + Sh^2$

$= 6 \times 2.5 + 2 \times 2.5^2 = 27.5\ m^2$

$P = b + 2h\sqrt{1+S^2}$

$= 6 + 2 \times 2.5\sqrt{1+4}$

$= 17.18\ m$

$D = A/B$; $B = b + 2Sh$

$= 6 + 2 \times 2 \times 2.5$

$= 16\ m$

$Fn^2 = \frac{\alpha v^2}{gD} = \frac{\alpha Q^2}{gDA^2} = \frac{1.12 \times 30^2}{9.81 \times \frac{27.3}{16}}$

$= 0.0835$

$\therefore \frac{d}{dx}(h_j) = \frac{0.0025 - 0.000397}{1 - 0.0835} = 0.00229$

$\therefore h_2 = h_j + \Delta x \left(\frac{d}{dx} h_j\right)$

$= 2.5 + (-100) \times 0.00229 = 2.271\ m$

Modified Euler method:

$$\left(\frac{d}{dx} h_j\right) = 0.00229$$

$$h_{j+1/2} = h_j + \frac{\Delta x}{2}\left(\frac{d}{dx} h_j\right)$$

$$= 2.5 + (-50) \times 0.00229 = 2.386 \text{ m}$$

$$\frac{d}{dx}(h_{j+1/2}) = \frac{S_0 - S_f}{1 - Fr^2}$$

$$= \frac{0.0025 - 0.000478}{1 - 0.0941}$$

$$= 0.00223$$

$$\therefore h_{j+1} = h_j + \Delta x \frac{d}{dx} h_j$$

$$= 2.5 + (-100)\, 0.00223$$

$$= 2.277 \text{ m}$$

$S_0 = 0.0025$

$A = bh + sh^2$

$= 6 \times 2.386 + 2 \times 2.386^2 = 25.7 \text{ m}^2$

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

$= 6 + 2 \times 2.386\sqrt{1+2^2} = 16.67 \text{ m}$

$B = b + 2sh$

$= 6 + 2 \times 2 \times 2.386 = 15.544 \text{ m}$

$$Fr^2 = \frac{\alpha Q^2}{g D A^2} = \frac{1.12 \times 30^2}{9.81 \times \frac{25.7^3}{15.544}}$$

$$= 0.0941$$

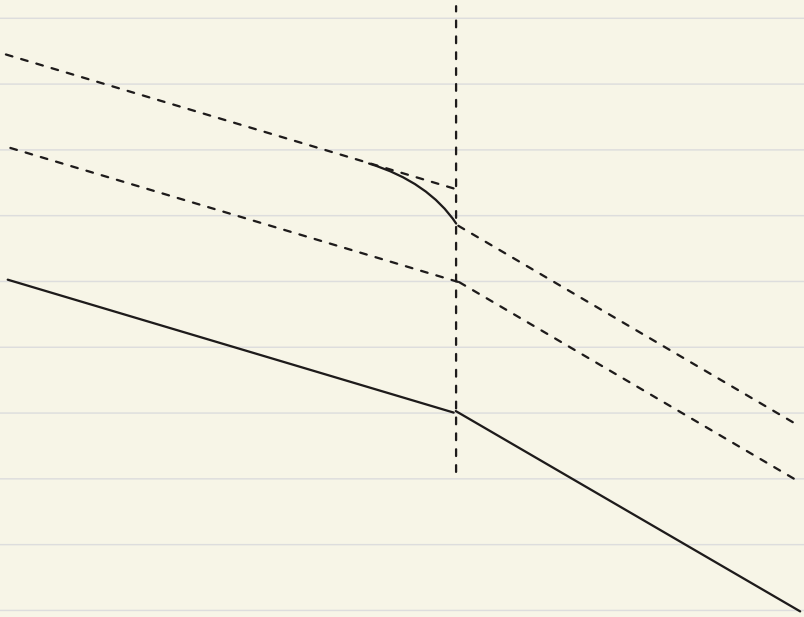
$$AR^{2/3} = \frac{nQ}{\sqrt{S_f}}$$

$$\Rightarrow (25.7)^{5/3} \times \frac{1}{16.67^{2/3}} = \frac{0.025 \times 30}{\sqrt{S_f}}$$

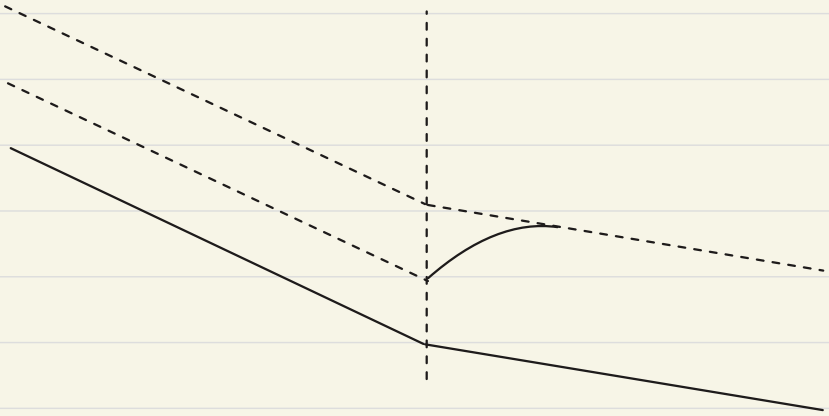
$$\Rightarrow S_f = 0.000478$$

Prob – 6.5

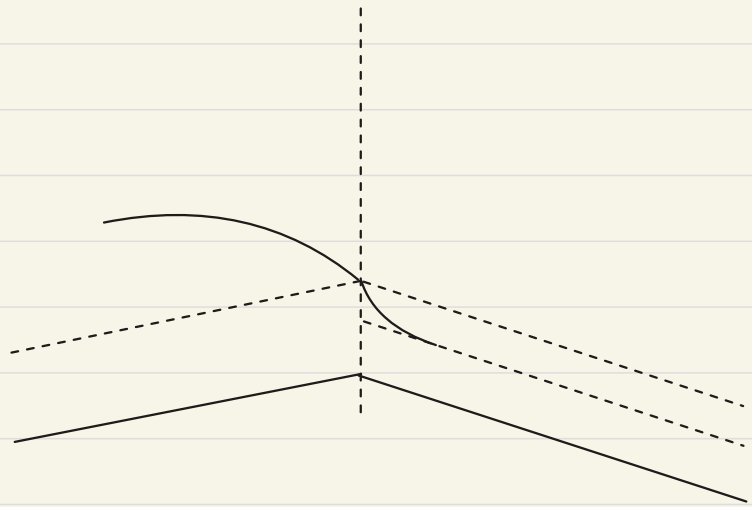
(i) mild – steeper mild



(ii) steep – critical

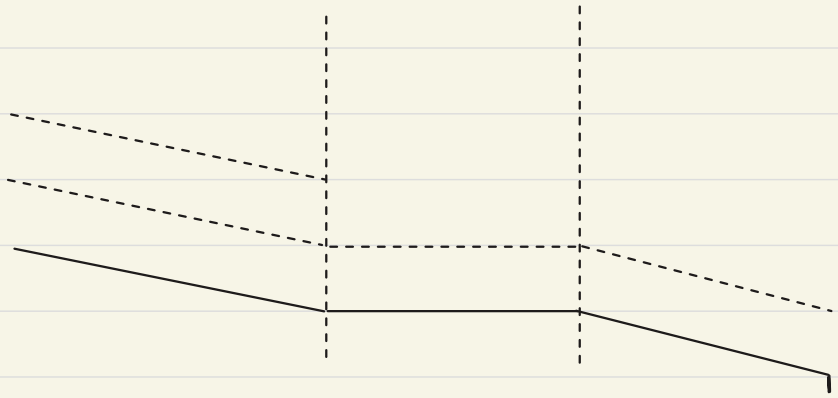


l) Advense — steep



Phase - 6.6

(g) Mild-hon-critical-free overfall:



(j) non – adverse – steep – free

