$\Rightarrow \dfrac{\text{Benefit}}{\text{cost}} = \dfrac{22382}{16650} = 1.344 \underline{\underline{\geq 1}}$

so financially justified.

## ⇒ DESIGN OF LINED CANALS

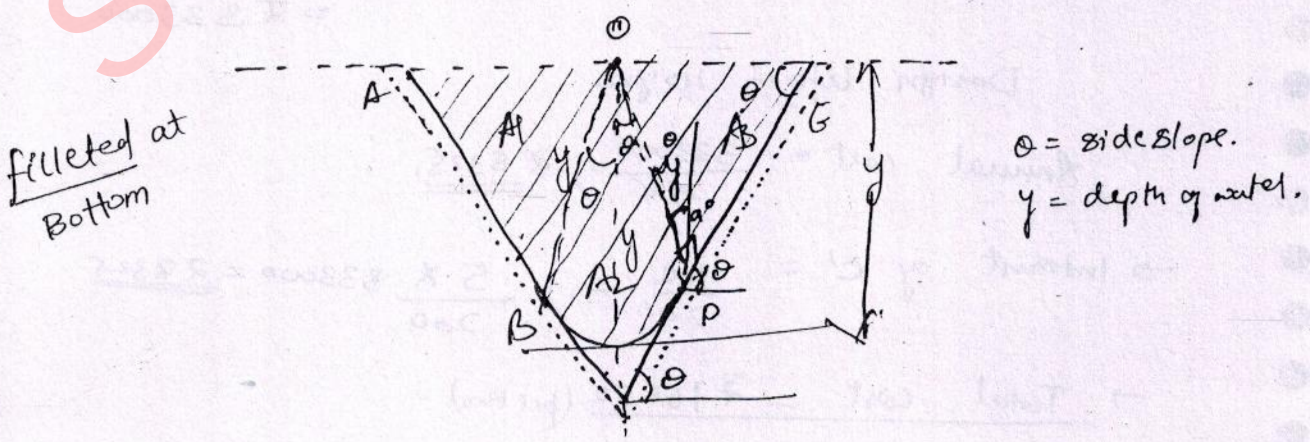
- The basis of designing of Lined ~~canals~~ is that whatever silt is entering into the channel is kept in suspension form. so that it does not settle at the base of channel.

(Note: the problem of scouring is negligible and Hence Ignored unlike in unlined).

- The Higher velocities of flow can be permitted in ~~the~~ lined channels by taking the advantage of Hard wearing surface and the section of the channel is designed should be the most efficient section.

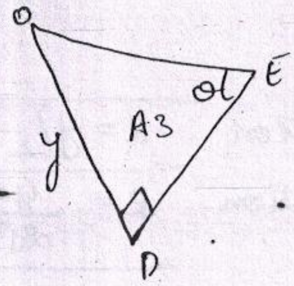
- Type of section provided in lined canals
  - ↳ (a) Triangular section ( $Q < 150\ m^3/s$ )
  - (b) Trapezoidal section ( $Q \geq 150\ m^3/s$ ,

## ⇒ TRIANGULAR SECTION :-



Area of section = $A_1 + A_2 + A_3$

Since symmetric section = $A_1 = A_3 = \frac{1}{2}(DE)(DO)$




$\tan\theta = \frac{y}{DE}$

$DE = y\cot\theta$

$\therefore A_1 = A_3 = \frac{1}{2} y \cdot y\cot\theta$

$$A_1 = A_3 = \frac{1}{2} y^2 \cot\theta$$

Area of sector subtending $2\theta$ = $\frac{\cancel{\pi} \cdot y^2}{\cancel{2}\cancel{\pi}} \times \cancel{2}\theta = y^2\theta$

$$\boxed{\begin{array}{ll} 2\pi & — \ \pi r^2 \\ 1 & — \ \frac{\pi r^2}{2\pi} \\ 2\theta & — \ \left(\frac{\pi r^2}{2\pi} \times 2\theta\right) \end{array}}$$

$\therefore$ Total Area = $2A_1 + A_2 = 2 \times \frac{y^2}{2}\cot\theta + y^2\theta$

Area of triangular channel $\boxed{A = y^2(\cot\theta + \theta)}$

Perimeter of $\Delta^{le}$ Channel $\boxed{P = 2y(\cot\theta + \theta)}$

$\Rightarrow$ PERIMETER = $L_{AB} + L_{BCD} + L_{DE}$

$L_{AB} = L_{DE} = y\cot\theta$

$L_{BCD}$ = length of an arc subtending $2\theta$

$= \frac{2\pi y}{2\pi}(2\theta) = 2y\theta$

$$R = \frac{A}{P} = \frac{y^2(\cot\theta + \theta)}{2y(\cot\theta+\theta)} = \frac{y}{2}.$$

$$\boxed{R = \frac{y}{2}.}$$

**Note**

in lined channel section $R = y/2$

in most efficient section $R = \frac{y}{2\sqrt{2}}$.

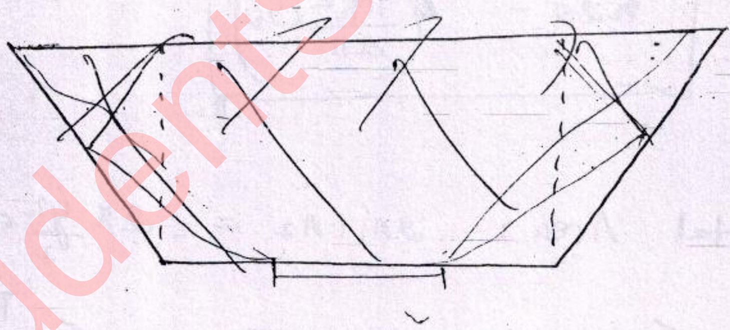
**Triangular Section**

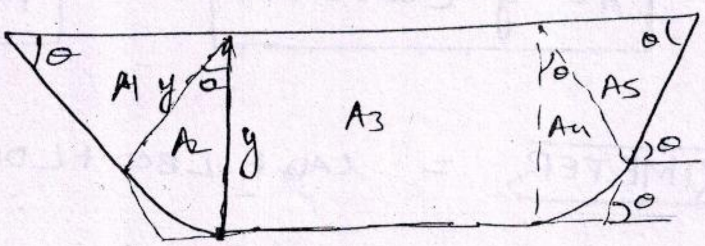
$A = y^2(\cot\theta + \theta)$

$R = y(\cot\theta + \theta)$

$R = \frac{y}{2}$

⇒ **TRAPEZOIDAL SECTION** $Q > 150\ m^3/s$.






Area = $A = A_1 + A_2 + A_3 + A_4 + A_5$.

$A_3 = By$

$y^2(\cot\theta+\theta)$

$$\therefore \boxed{\begin{aligned} A &= By + y^2(\cot\theta + \theta) \\ P &= B + 2y(\cot\theta + \theta) \end{aligned}}$$ for trapezoidal Canal.

## ⇒ DESIGN STEPS FOR LINED CHANNELS :-

1) Permissible velocity of flow in the lined ~~ch~~ channels for different types of material is assumed to be in following Range.

| | | |
|---|---|---|
| concrete | — | 2 - 2.5 m/s |
| Clay | — | 1.8 m/s. |
| Boulder | — | 1.5 m/s. |

(2) Calculate the Hydraulic Mean Depth (R) for the given slope of channel (i.e longitudinal slope).

$$V = \frac{1}{N} \cdot R^{2/3} \cdot S^{1/2} \Rightarrow R = ?$$

(3) Calculate the area of flow for the given discharge

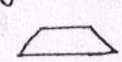
$$A = \frac{Q}{V}.$$

(4) Calculate the perimeter of flow. $P = \frac{A}{R}$

Now, equating Area & perimeter to the formula.

$$A = \frac{Q}{V} = y^2(\cot\theta + \theta) \quad \text{or} \quad By + y^2(\cot\theta + \theta)$$

(Δ)



$$P = \frac{A}{R} = 2y(\cot\theta + \theta) \quad \text{or} \quad B + 2y(\cot\theta + \theta)$$

Calculate y & θ from above eqn.

θ = channel side slope.

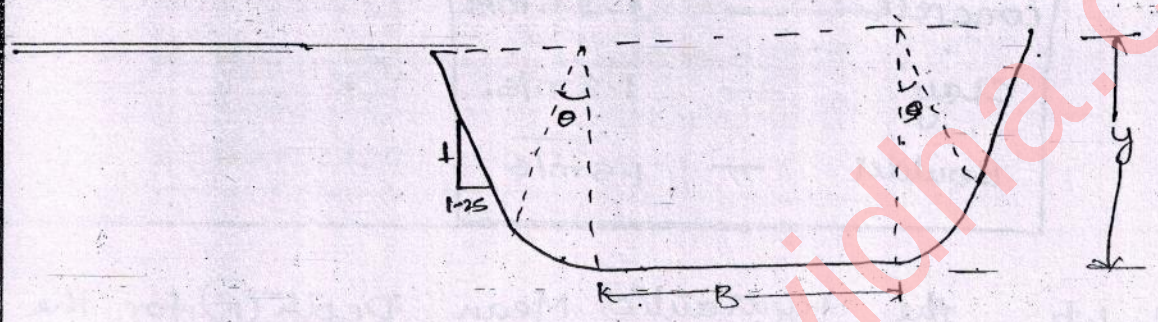
(V) Assume channel side slope 1.25H : 1V to 2H : 1V.

---

**Q** Design a lined channel to carry 100 m³/s of discharge on a slope of 1 : 2500. Maxm permissible velocity is 2 m/s. Roughness coeff (N) = 0.013 and the side slope is 1.25 H to 1V.

Design a trapezoidal section.

**Sol:** if shape is not given — prefer Triangular section.




$Q = 100\ m^3/s$.

$V = 2\ m/s$

$\tan\theta = \frac{1}{1.25} \Rightarrow \theta = 38.659$.

$\theta = 0.674\ rad$.

$V = \frac{1}{N} \cdot R^{2/3} \cdot S^{1/2}$.

$2 = \frac{1}{0.013} \cdot R^{2/3} \cdot \left(\frac{1}{2500}\right)^{1/2}$

$R = 1.48m$.

(II) $A = \frac{Q}{V} = \frac{100}{2} = 50\ m^2$

(III) $P = \frac{A}{R} = \frac{50}{1.48} = 33.78m$.

$A = By + y^2(\cot\theta + \theta)$

$50 = By + y^2(\cot 38.65° + 0.674)$

~~$P = B + 2y\sqrt{1+n^2}$~~

$P = B + 2y(\cot\theta + \theta)$

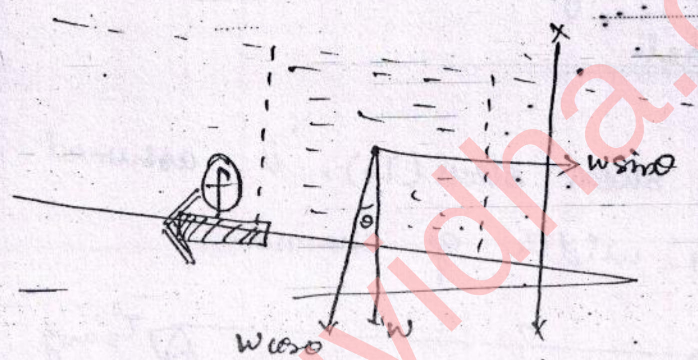
$33.78 = B + 2y(\cot 38.65 + 0.$

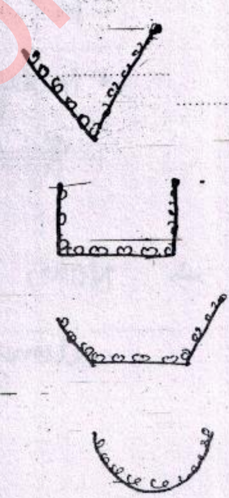
~~$50 = By$~~

$B = 27.45\,m.$

$y = 1.634\,m.$

## ⇒ SEDIMENTS TRASPORT MECHANICS



→ Average Shear Stress at the Bottom of Channel. $\tau_0 = \dfrac{\text{Shear force}}{\text{Area on which Shear force is Acting}}$

Note : Shear force = tangential force.
↓ f Eq w sinθ.

as its non accelerated flow, the velocity remains constant.
⇒ $f = w\sin\theta$.

$\therefore\ \tau_0 = \dfrac{f}{HL + BL + HL} = \dfrac{f}{(B+2H)L} = \dfrac{f}{P.L}$

P → Perimeter.

$f = w \sin\theta$

if $\theta$ is small $\quad \theta = \sin\theta \approx \tan\theta \approx S.$

$W = \gamma_w \cdot \text{volume} = \gamma_w \cdot AL.$

$\Rightarrow \tau_0 = \dfrac{\gamma_w \cdot A\cancel{L} \cdot S}{P \cdot \cancel{L}} = \gamma_w \cdot R \cdot S.$

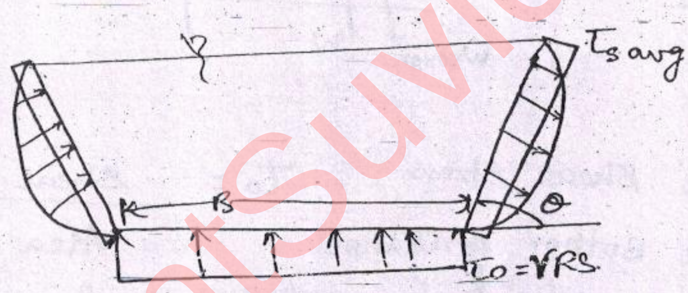
$\boxed{\tau_0 = \gamma_w \cdot R \cdot S}$

- in case of water
- independent of c/s of channel.

$\boxed{\tau_0 = \gamma \cdot R \cdot S}$

- in case of any other material.

$\Rightarrow$ Now, Avg shear stress ($\tau_0$), is assumed to be constant along the width of channel.




$\rightarrow$ The shear stress is uniform

- The shear stress at the side surface is not uniform and varies parabolically.
- The shear stress at the side surface is less than the shear stress at the Base

$\tau_{s(avg)} < \tau_0,$

$\tau_{s(avg)} = 0.75\,\tau_0.$

$\tau_{s(avg)} = 0.75(\gamma \cdot R \cdot S)$

- The critical value of shear stress at which particles present at the base of channel starts moving, can be calculated by the SHIELS EQN.

SHIELD'S EQN

$$\boxed{\tau_c = 0.056\,(G_s - 1)\,\gamma \cdot d}$$ (sp.gr) $d = mm$.

- If the stress is equal or more than the critical shear stress, than the particle at the base starts moving with the current.

∴ it silt so inorganic material.

i.e $G_s$ = inorganic material specific Gr.

$G_s = 2.65$ [Range 2.6 – 2.9).

$$\tau_c = 0.056(2.65-1)\gamma d.$$

$$\tau_c = 0.0924\,\gamma d$$

$$\boxed{\tau_c = \frac{\gamma d}{11}}$$

⇒ for no movement of particle from the Base of the ~~particle~~ channel. i.e

for No scouring $\boxed{\tau_o \leq \tau_c}$

$$\gamma \cdot R \cdot S \leq \frac{\gamma \cdot d}{11}$$

$$\boxed{R \leq \frac{d}{11 \cdot S}} \qquad \boxed{d = 11 \cdot R \cdot S}$$

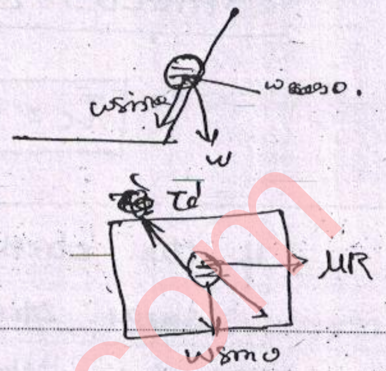
$d = mm$

$R = m$.

⇒ for No Movement of particle from the side surface of the channel, the avg shear stress at side surface should be less than or equal to critical shear stress at side surface.

i.e

$$\boxed{\tau_{c\,avg} \le \tau_c'} \quad \text{—(i)}$$




$\mu = \tan\phi$

if $\phi = 0$, $\mu = 0$, so only $w\sin\theta$ in consideration

$$\frac{\tau_c'}{\tau_c} = \sqrt{1 - \frac{\sin^2\theta}{\sin\phi}}$$

$$\boxed{\frac{\tau_c'}{\tau_c} = \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}}$$

$\sin\theta = \frac{1}{\sqrt{1+n^2}}$ ; n = side slope.

$\phi$ = internal friction angle

from (i)

$$\Rightarrow \tau_{c\,avg} \le \tau_c \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

$$0.75\,\tau_0 \le \tau_c \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

$$0.75 \cdot \gamma \cdot R \cdot S \le \frac{\gamma d}{11} \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

$$\boxed{R = \frac{4}{33}\,\frac{d}{S} \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}}$$

|Q|| An unlined irrigation Cannal has its bed and side composed to cohesionless material Having the mean dia of 6mm. And frictional angle of 45°. The bed width of the canal is 5m and side slope is 1.5H : 1V.

Determine the discharge that can be admitted into the canal without any sediment movement. The longitudinal slope of the channel is $\frac{1}{5000}$ and $N = 0.025$.

**Sol**

i) for No Scouring from Base.

$$R_{(m)} \le \frac{d}{11 \cdot S}$$

$$d = 6mm \quad ; \quad S = \frac{1}{5000}.$$

$$R \le \frac{6 \times 10^{-3}}{11 \times \frac{1}{5000}} \Rightarrow \boxed{R \le 2.727m.}$$

ii) for No scouring frome side.

$$R \le \frac{4}{33}\frac{d}{S}\sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

$$\phi = 45° \quad \sin 45 = \frac{1}{\sqrt{2}} \Rightarrow \sin^2 45 = \frac{1}{2}$$

$$\sin\theta = \frac{1}{\sqrt{1+n^2}} = \frac{1}{\sqrt{1+1.5^2}}$$

$$\sin^2\theta = \frac{1}{(1+1.5^2)} = 0.307.$$

$$R \le \frac{4}{33} \times \frac{6 \times 10^{-3}}{\frac{1}{5000}} \left(\sqrt{1 - \frac{.307}{0.5}}\right).$$

$$\boxed{R \le 2.255\,m}$$

so, for No scouring from Both side

take the minimum of R

$\therefore$ $\underline{R = 2.255\,m.}$

$R = \frac{A}{P}$ ; $A = (B+ny)y.$

$P = B + 2y\sqrt{1+n^2}$

$$2.255 = \frac{(B+ny)\,y}{B + 2y\sqrt{1+n^2}}$$

$$2.255 = \frac{(5+1.5y)\,y}{(5+2y\sqrt{1+1.5^2})}$$

$y = 3.97\,m.$

$\therefore A = (5 + 1.5 \times 3.97)\,3.97 = 43.49\,m^2.$

$Q = AV.$

$V = \frac{1}{N} \cdot R^{2/3} \cdot S^{1/2}.$

$= \frac{1}{0.025} \cdot (2.2554)^{2/3} \cdot \left(\frac{1}{5000}\right)^{1/2}$

$V = 0.97\,m/s.$

$Q = 43.49 \times 0.97 \Rightarrow \underline{Q = 42.27\,m^3 s}$