Channel Design

Definition: Channel design is determination of section dimensions to convey the required discharge.

Factors:

1. The kind of materials forming the channel body. Which determines the roughness coefficient.

2. The minimum permissible velocity
3. To avoid deposition.
4. The channel slope or bed slope.
5. Freeboard
6. Most efficient channel section.

Types:

1. Erodible channel 2. Non erodible "	Alluvial Channel

1 Erodible channels: Most unlined channels are called Erodible Channels.

2. Non erodible channel: Most lined and builtup channels can withstand erosion, these are called Non-n erodible channels. Maximum permissible velocity and the permissible tractive force are not the criteria to be considered.

Alluvial channel: — transfers water as well as sediment, silt
- Stability depends of sediment inflow and the sediment outflow to be equal.

Most efficient ...

A. Non erodible channels

Linings:— meaning the earth surface is linked with the lining surface such as concrete.

- purpose of linings is for ~~se~~ preventing erosion and to check seepage losses.

- maximum permissible velocity can be ignored

The minimum Permissible Velocity: - is the minimum velocity for which no sedimentation will occur. It's also called non silting velocity.

It's:

- uncertain, exact value can't be determined
- Mean velocity 2-3 fps
- >2.5 fps will decrease ~~prev~~ vegetation.

The maximum Permissible Velocity:

It's the highest velocity that won't cause erosion. It's also known as non-erodible velocity.

V.I

Freeboard: - The vertical distance from the top of the channel to the water surface.

- importantion for designing elevated flumes.

- These are 30% - 5% of depth of flow.

$F = \sqrt{cy}$, $c = 1.5 - 2.5$

$\downarrow$ 200cfs $\downarrow$ 3000cfs

回 Most efficient or Best Hydraulic Section:

$Q = \frac{1.49}{n} R^{2/3} S^{1/2} A$ $\therefore \boxed{Q \propto R^{2/3}}$

$\Rightarrow Q = K\sqrt{S}$

$\therefore K = \frac{1.49}{n} R^{2/3} A$

$= \frac{1.49}{n} \frac{A^{2/3}}{P^{2/3}} A$

$\therefore K = \frac{1.49}{n} \frac{A^{5/3}}{P^{2/3}}$

$\therefore \boxed{K \propto \frac{1}{P^{2/3}}}$ $\therefore$ The section with lest wetted perimeter will be the best.

$\therefore$ If a channel section has least P wetted perimeter it'll have the maximum conveyance, such a section is called best hydraulic section.

- Semicircle- least wetted perimeter, but not a practical design.
- The principle of best hydraulic section is only for non-erodible sections.
- For erodible Sections, tractive force must be used.

N20·01

#Problem: Rang-Raju Ex 4.1

A rectangular section is to be built of rough unsized timber. If given a drop of 2m in a km, what will be the width and depth for the most efficient section if it has to carry 1.1 m^3/s ? n=0.011

Ans: Here,

$S = \frac{2}{1000}$

$n = 0.011$

$Q = 1.1$

$b = ?$

$y = ?$

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

For most efficient rectangular section,

$b = 2y$, $R = \frac{y}{2}$, $A = by = 2y^2$

$\therefore 1.1 = \frac{1}{0.011} \left(\frac{y}{2}\right)^{2/3} \left(\frac{2}{1000}\right)^{1/3} \times 2y^2$

$\therefore y = 0.561$ m

$\therefore b = 2 \times 0.561 = 1.12$ m

Ans.

#Problem: Ranga Raju 4.2

A trapezoidal chanel of most efficient section has side slopes 1:1, It is required to carry a discharge of 25 m^3/s with a slope of 1 in 1500. Design the section if n=0.0135

Ans: We know, for most efficient trapezoidal sections,

$y\sqrt{1+z^2} = \frac{b+2yz}{2}$

$\Rightarrow y\sqrt{2} = \frac{b+2y}{2}$

Here,

$Q = 25\ m^3/s$

$S = \frac{1}{1500}$

$z = 1$

$n = 0.0135$

$\therefore b = 2\sqrt{2}\,y - 2y$

And, $A = \frac{1}{2} y\,(2b + 2yz) = y\,(b + yz)$

$= y(2\sqrt{2}\,y - 2y + y)$

$= 2\sqrt{2}\,y^2 - y^2$

$\therefore A = 1.828\,y^2$

$\therefore$ From mannings formulae,

$$25 = \frac{1}{0.0135} \left(\frac{y}{2}\right)^{2/3} \left(\frac{1}{1500}\right)^{1/2} 1.828 y^2$$

$\therefore y = 2.486$ m

$\therefore b = 2.059$ m

$\therefore T = 7.031$ m

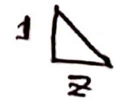
$\therefore$ Sloping side $= y\sqrt{1+z^2} = T/2 = 3.51$ m Ans:

Problem: khurmi 16:16 (2019)

A trapezoidal channel has side slope 2 vertical to 3 horizontal. It is discharging water at the rate of 20 cumes with a bed slope 1 in 2000. Design the channel for it's best form. Use Manning's formulae, taking N=0.01.

Solution: Side slope 2 vertical to 3

$\therefore$ " " 1 " " $\frac{3}{2} = 1.5$



$\therefore z = 1.5$

$\therefore z = 1.5$

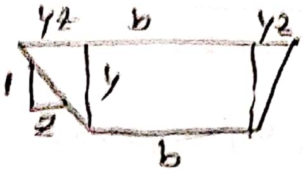
$Q = 20$ cumecs $= 20\ m^3 s^{-1}$

$S = 1/2000$

$N = 0.01$

For trapezoidal section,

$A = \frac{1}{2} y(2b + 2yz)$



$\therefore A = y(b + zy) = y(b + \overset{1.5}{z}y)$

And for most efficient section,

$y\sqrt{1+z^2} = \frac{b+2yz}{2}$

$\Rightarrow 2\sqrt{2}\, y = b + 2y$

$\therefore b = 2\sqrt{2}\, y - 2y$

$\therefore A = y(2\sqrt{2}y - 2y + y)$

$= y(2\sqrt{2}y - y)$

$A = 1.828 y^2$

$\therefore$ From manning's formulae,

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

$\Rightarrow$

$\Rightarrow y\sqrt{1 + 1.5^2} = \frac{b + 3y}{2}$

$\Rightarrow \sqrt{3.25} \times 2 \times y = b + 3y$

$\therefore b = 0.6055 y$

$\therefore A = y(0.6055y + \overset{1.5}{z}y)$

$= \cancel{3.6055y^2} = 2.1y^2$

From manning's formulae,

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

$\Rightarrow 20 = \frac{1}{0.01} \times (y/2)^{2/3} \times (1/2000)^{1/2} \times 2.1\cancel{3.6055}y^2$

$\therefore y = 2.05\,m$

$\therefore b = 0.6055 \times 2.05 = 1.24\,m$

$\therefore$ Side slope $= y\sqrt{1+z^2} = 3.69\,m$

$\therefore$ Top width, $T = b + 2yz = 7.39\,m$

Answer.

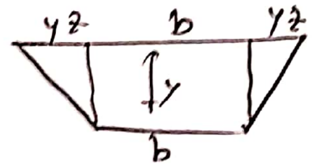
Problem: Khunmi 16.18

A brick lined trapezoidal canal has side slopes of 1.5 horizontal to 1 vertical. It is required to carry 15 cubic meters of water per second. If the average velocity of flow is not to exceed 1 m/s, find

(a) the wetted perimeter for minimum amount of lining

(b) bed slope, assuming Manning's N = 0.015

Solution:



$Z = 1.5$

$Q = 15\ m^3/s$

$V = 1\ m/s$

$N = 0.015$

$S = ?$

Here,

$$A = \frac{1}{2} y(2b + 2yz) = y(b + yz)$$

$$\therefore A = y(b + 1.5y)$$

$$\Rightarrow \frac{Q}{V} = y(b + 1.5y)$$

$$\Rightarrow 15 = y(b + 1.5y) \quad \text{——} (1)$$

$$\Rightarrow$$

Again,

for minimum amount of lining we need most efficient section,

$$\therefore y\sqrt{1+z^2} = \frac{b + 2yz}{2}$$

$$\Rightarrow \sqrt{3.25} \times 2 \times y = b + 3y$$

$$\therefore \cancel{b = 3.5y} \quad b = 0.6y$$

from (1)

$$15 = y(\cancel{3.5y}\ 0.6y + 1.5y)$$

$$\Rightarrow 15 = y \times \cancel{5y}\ \cancel{3.37y}\ 2.1y$$

$$\Rightarrow 15 = \cancel{5y^2}\ \cancel{3.37y^2}\ 2.1y^2$$

$$\therefore y = 2.67\ m$$

$$\therefore b = 1.6\ m$$

$\therefore$ wetted perimeter,

$$P = b + \cancel{2yz}\ 2y\sqrt{1+z^2}$$

$$= 1.6 \cancel{+ 2 \times 2.67 \times 1.5}$$

$$\cancel{= 9.61}$$

$$= 1.6 + 2 \times 2.67\sqrt{1 + 1.5^2}$$

$$= 11.2\ m$$

We know,

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

$$\Rightarrow 1 = \frac{1}{0.015} \times \left(\frac{2.67}{2}\right)^{2/3} S^{1/2}$$

$$\therefore S = \frac{1}{6535}$$

Answer.

B. Erodible channels

The uniform-flow formula is not suitable for ~~suitable~~ designing a erodible channels. Because the stability of the Channel depends on the properties of the materials forming the channel body.

Methods of Approch:
Only after a stable section is obtained, the uniform flow formulae can be applied for compuling the velocity of flow and discharg.

Two methods of design are:
(i) Method of permissible velocity
(ii) Method of tractive force

(i) Method of maximum permissible velocity:

Definition: It's the greatest mean velocity for which scouring or erosion of channel body will not occur. It's also known as non-erodible velocity.

- This velocity is uncertain and variable.
- Old and well seasoned channels will withstand higher velocities.
- Deeper Channel will withstand higher velocities than a Shallower one.

Using the maximum permissible velocity as criteron, assuming trapezoidal section the design procedure is—

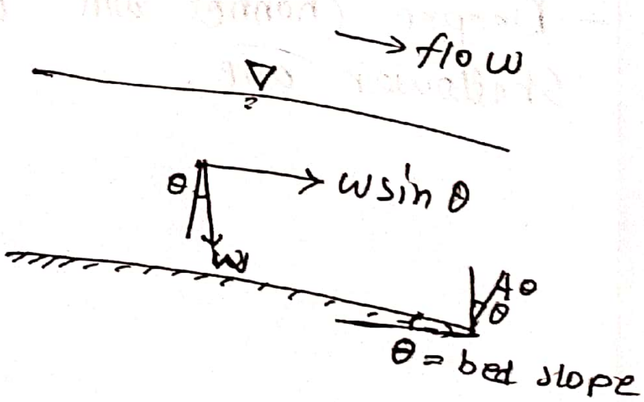
1. Estimate roughness co-eff n, side slope z, max permissible velocity V
2. Compute R by mannings formulae
3. Compute water Area, $A = Q/V$
4. wetted perimeter, $P = \frac{A}{R}$
5. Get b, y from A & P
6. Add free board.

② Method of Tractive force:

Tractive force:

when water flows in a channel, a force is developed in the direction of flow. This force is simply is the pull that acts on the water is unown as tractive force.

In uniform ~~fa~~ flow this force is equal to the effective component of gravity force acting on the body of water,



Here,

$\tau = W \sin\theta$

$= W \tan\theta$

$= W S$

$= \omega A L S$

$\therefore \boxed{\tau = \omega A L S}$

L = length of channel

A = wetted area

ω = unit weight of water

* What is unit tractive force? Draw Pressure Diagram.

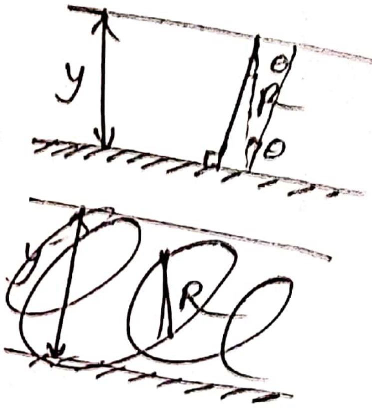
The average tractive force per unit wetted area is called unit tractive force.

Here, wetted Area = PL of total channel

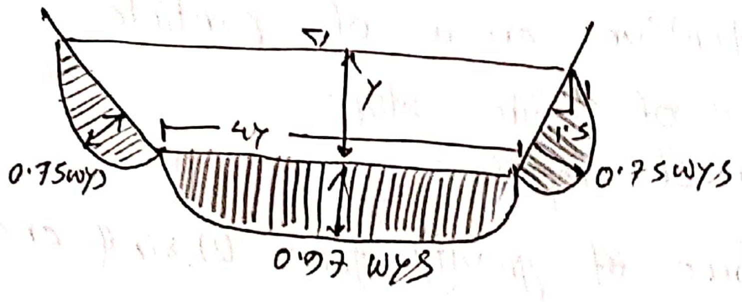
$\therefore$ Unit tractive force = $\tau_0 = \frac{\omega ALS}{PL}$

$= \omega \frac{A}{P} S$

$\therefore \boxed{\tau_0 = \omega RS}$



* Unit tractive force isn't uniformly distributed along the wetted perimeter.

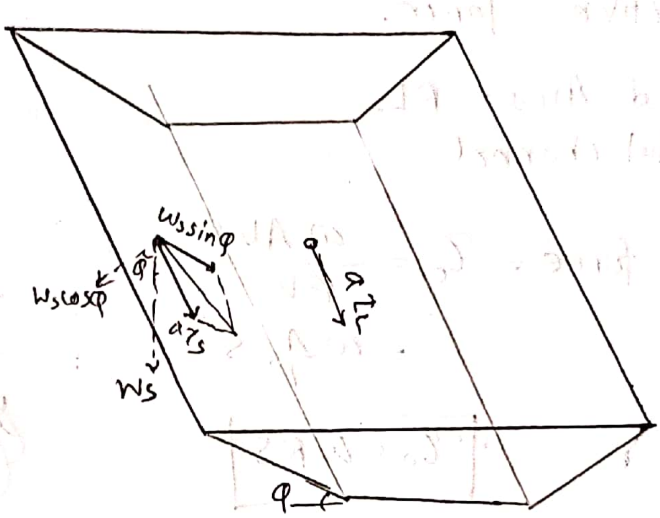


Tractive force Ratio:

* What's Tractive force ratio? Prove it, tractive force ratio is a function of inclination of sloping side and of the angle of repose of the material forming the channel bed. Give sketches. (20,20)

Solution: The ratio of two unit tractive forces acting on a soil particle resting on the sloping side and and on the level surface respectively, is known as tractive force ratio (K)

$\therefore k = \dfrac{\tau_s}{\tau_L}$



Here, τ_s = unit tractive force on sloping side
τ_L = " " " level side
a = effective area of particle
φ = angle of side slope
θ = angle of repose

Resultant force of gravity force $W_s \sin\varphi$ and tractive force $a\tau_s$

$$= \sqrt{(W_s \sin\varphi)^2 + a^2\tau_s^2}$$

The resistant to motion = ~~$W_s \tan$~~ $(W_s \cos\varphi) \tan\theta$

Hence,

$$W_s \cos\varphi \tan\theta = \sqrt{W_s^2 \sin^2\varphi + a^2\tau_s^2}$$

$$\Rightarrow W_s^2 \cos^2\varphi \tan^2\theta = W_s^2 \sin^2\varphi + a^2\tau_s^2$$

$$\Rightarrow a^2\tau_s^2 = W_s^2 \cos^2\varphi \tan^2\theta - W_s^2 \sin^2\varphi$$

$$\Rightarrow \tau_s^2 = \frac{W_s^2 \cos^2\varphi \tan^2\theta}{a^2}\left(1 - \frac{\sin^2\varphi}{\tan^2\theta \cos^2\varphi}\right)$$

$$\Rightarrow \tau_s = \frac{W_s \cos\varphi \tan\theta}{a}\sqrt{1 - \frac{\tan^2\varphi}{\tan^2\theta}}$$

Again, for the particle on leveled surface,

$\varphi = 0$

$\therefore \tau_L = \dfrac{w_s \tan\theta}{a}$

$\therefore$ Tractive force ratio $k = \dfrac{\tau_s}{\tau_L}$

$$= \cos\varphi \sqrt{1 - \frac{\tan^2\varphi}{\tan^2\theta}}$$

$$\therefore k = \sqrt{1 - \frac{\sin^2\varphi}{\sin^2\theta}}$$

(Proved)

Permissible Tractive force:

It's the maximum unit tractive force that won't cause erosion to the channel bed on the leveled surface.

Critical Tractive Force: 2020

The permissible unit tractive force that can be determined by laboratory experiment are called ~~coat~~ critical tractive force.

- however, actual canals of coarse - non cohesive material can stand higher values of of tractive force than critical tractive force. It's because of the binding power from colloidal and organic matter.

(2020

Problem: Ven Te chow - Ex 7.4

Design a trapezoidal channel laid on a slope of 0.0016 and carrying a discharge of 400 cfs. The channel is to be excaveted in earth containing non-coloidal coarse gravels and pebbles, 25% of which is 1.25 inch or over in diameter. Given, n = 0.025, side slope 2:1, angle of repose 33.5°.

$f(x, y)$

Solution:

Using maximum permissible velocity method:

For non colloidal coarse gravels and pebbles, maximum permissible velocity, V = 4.5 fps

$n = 0.025$, $z = 2$

$Q = 400$ cfs

$S = 0.0016$

$$A = \frac{Q}{V} = \frac{400}{4.5} = 88.87 \ ft^2$$

$$\therefore V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

$$\Rightarrow 4.5 = \frac{1.49}{0.025} R^{2/3} (0.0016)^{1/2}$$

$\therefore R = 2.6'$

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

$$\Rightarrow P = A/R = \frac{88.87}{2.6} = 34.18'$$

Now,

$P = b + 2yz = \cancel{b + 2 \times 2y} = b + 4y = 34.18$ $\therefore b = 34.18 - 4y$

$A = y(b + yz) = y(\cancel{b + 2y}) = \cancel{88.87}$

$\Rightarrow y(34.18 \cancel{- 4y + 2y}) = \cancel{88.8}$ $\therefore y =$

$P = 2y\sqrt{1+z^2} + b$

$= b + 2\sqrt{5}\,y = 34.18 \quad \therefore b = 34.18 - 2\sqrt{5}\,y$

$A = y(b + yz) = y(b + 2y) = 88.8$

$\Rightarrow y(34.18 - 2\sqrt{5}\,y + 2y) = 88.8$

$\Rightarrow 34.18y - 2.47y^2 - 88.8 = 0$

$\therefore y = 3.46$ ft

$\therefore b = 18.7$ ft

Ans:

Shield's method of analysis:

Critical Tractive force, $\boxed{\tau_c = \tau_c' \, g (\Delta\rho) d}$ where,

$\Delta\rho = \rho_s - \rho_w$

$\rho_s = S.G \times \rho_w$

For gravel, $S.G = 2.65$

And $\boxed{\tau_0 = \rho_w g R S}$

If $\tau_0 > \tau_c$ particles will move,

Then, $\boxed{R' = \left(\frac{\Delta\rho}{\rho_w}\right)^{1/3} \frac{g^{1/3} d}{\nu^{2/3}}}$ | ν = kinematic viscosity

$= 25.3 \rightarrow$ for 1mm gravel

$\left\{\therefore \tau_c' = 0.035\right\}$

2018

#Problem: Water flows at a depth of 0.3m in a wide stream having a slope of 1×10^{-3}. The median dia of the sand bed is 1mm. Determine whether the grain are stationary or moving. Given, $\nu = 10^{-6}\ m^2/s$

Solution: Here,

$R = h = 0.3m$ [because in wide Channel, R=y]

$S = 10^{-3}$

$d = 10^{-3} m$

$\nu = 10^{-6}$

$\therefore$ ~~Bec~~ For 1mm gravel we know, $\tau_c' = 0.035$

$\therefore \tau_c = \tau_c' g (\Delta\rho) d = 0.035 \times 9.8 \times (2650 - 1000) \times 10^{-3}$

$= 0.565$

$\tau_0 = \rho_w g RS$

$= 9.8 \times 1000 \times 0.3 \times 10^{-3} = 2.94$

$\because \tau_0 > \tau_c \quad \therefore$ Grains will be moving.

Answer:

2017, 2015

#Problem: Rang Raju Ex 4.5