Lecture - 3

Ex: Design the cross-section for unlined canal to carry a discharge of $1.6m^3/s$, if the longitudinal slope of the canal is 30cm/km, water contain light loamy suspended material and the bad material is a loamy silt. (n=0.025, max.tractive force is 2.8 N/m^2).

Sol:

By trial and error solution with Manning equation

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

$Q=1.6m^3/s$, n=0.025, S=30cm/km=0.0003

Assume side slope 1:Z, 1:2 for unlined canal

B/y=2-3

Assume b=2m, y=1m $\longrightarrow$ b/y=2 (2-3) o.k

$A = (b + zy)y \rightarrow A = (2 + 2 \times 01) \times 1 = 4m^2$

$P = b + 2y\ (1 + z^2)^{0.5} = 6.472m$

$R = A/P = 0.618m$

$Q = 1/0.025\ (0.0003)^{0.5}\ (4)\ (0.618)^{2/3}$

$Q = 2.011m^3/s > 1.6m^3/s$

$Assume\ b = 2, m\ y = 0.9m \rightarrow b/y = 2.222\ (2 - 3)\ o.k.$

$A = (2 + 2 \times 0.9)0.9 = 3.42m^2$

$P = 2 + 2 \times 0.9\sqrt{4 + 1} = 6.025m$

$R = 0.568m$

$Q = 1/0.025 \times (0.0003)0.5(3.42)\ (0.568)2/3$

$Q = 1.625m^3/s \approx 1.6m^3/\ s\ (\mp 4\%)\ o.k.$

Check for velocity:

$V = Q/A = 1.6/3.42 = 0.468m/s$

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$Vmin \ = C_2 y^{0.64} \ .from\ the\ table\ C_2 = 0.4$

$Vmin = 0.374 m/s$

$Vmax \ = c_1 y^{0.64} \ .from\ table\ C_1 = 0.66$

$Vmax. = 0.617 m/s$

$Vmine < V < Vmax$

0.374 < 0.468 < 0.617

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*Check for scouring by attractive force method.

$\tau = w * R * s = 9.81 * 1000 * 0.568 * 0.0003$

$\tau = 1.671\ N/m^2$

$\tau < \tau_c$ The bed will not scour.

Design values b=2m, y=0.9m

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Design by lacey's method

Assumption:

a• the channel flow is uniform.

b•the characteristics and the discharge of the sediment are constant.

c• the water discharge in the channel is constant.

Lacey's eq:

$Dm=2.46V^2/F$

$Ws=4.83\ e\ Q^{1/2}$

$$S = 0.0003\ f^{5/3}\ e^{1/3}\ \frac{E}{Q^{1/6}}$$

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

Where:

Dm=mean depth (m).

V=mean velocity (m/s).

F=silt factor (to account the size and density of sediment)

e= width factor or reduction factored, d=median size of sediment.

Ws=water surface width (m).

E=wetted parameter per water surface width (P/Ws).

Q=discharge (m^3/s).

S=water surface slope (m/m).

$$b = 0.8\ Ws$$

Dm=A/Ws

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*for main and branch canal e=1

*for distributaries with discharge (1-2m^3/s), (e=0.75-0.85)

*sill factor f=0.4-1, f=1.0 for large discharge.

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f=0.7-1 at north Iraq

f=0.6 at middle of Iraq

f=0.5 south of Iraq

Ex: Design a stable channel for carrying a discharge of 1m^3/s using Lacey's Method assuming silt factor equal to 0.75.

Sol:

$$Assume \quad e = 0.75$$

$$Dm = 2.46\,V^2 \quad ; \; Dm = 3.28V^2$$

$$Dm = A/Ws \rightarrow \; 3.28V^2 = A/Ws \; \rightarrow \; A = 3.28V^2Ws$$

$$Ws = 4.83 \;\; e\,Q^{1/2}$$

$$Ws = 4.83(0.75)\;(1)^{1/2} = 3.622m$$

$$A = 3.28V^2\;(3.622)$$

$$A = 11.882V^2$$

$$Q = AV \;\rightarrow\; V = \frac{Q}{A} = \frac{1}{A}$$

$$A = 11.882/A^2$$

A^3=11.882 ⟶ A=2.282m^2

b=0.8 Ws=0.8×3.662

b=2.9m

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$$A = \left(\frac{b + Ws}{2}\right) y$$

2.282= (2.9+3.622/2)/y

y=0.7m

$S=0.0003\ f^{5/3}\ e^{1/3}\ E/Q^{1/6}$

E=P/Ws,P=4.475m

E=4.475/3.622=1.24

$S=0.0003(0.75)^{1/3}(0.75)^{5/3}\{1.24/(1)^{1/6}\}$=0.000209.

S= 20cm/km

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KENNEDY SILT METHOD

Kenned'y collected data from 22 channels of upper Bari Doab canal system in Punjab. His observation let to following relation .known as Kennedy's equation

$V_{\circ} = 0.55\ h^{0.64}$

Where:

$V_{\circ}$: The critical velocity (m/sec) which defined as the mean velocity

Which will not allow scouring or silting in channel having depth to h (m).

This eq.is, obviously applicable to such channels which have the same

Type of sediment as was present in the upper Bari Doab canal system.

On recognizing the effect of the sediment size on the critical velocity, Kennedys modified the above equation to:

V =0.55 m $h^{0.64}$

Where:

(m) is the critical velocity ratio and is equal to m $\frac{v}{V_{\circ}}$.here. The velocity (V) is the critical velocity for the relevant size of sediment of any other silt grade while ($V_{\circ}$) is the critical velocity for the upper Bari Doab sediment. This means that the value of (m) is unity for sediment of the size of Upper Bari Doab sediment. For sediment coarser is greater than one, while for sediment finer, m is less than one. Kenned'y did not try to establish any other relationship for the slope of the regime channels in terms of either the critical velocity or the depth of the flow. He suggested the use of the Kutter's eq. along the manning roughness coefficient. The final results do not differ much if one uses the manning eq. instead of the Kutter's eq.

Kutter's equation

$$V = \left(\frac{\frac{1}{n} + (23 + \frac{0.00155}{s}}{1 + \frac{(23 + \frac{0.00155}{s}}{n\sqrt{R}}} \right) \sqrt{RS}$$

NOTE: this critical velocity should be distinguished from the critical velocity of flow in open canal corresponding to froud no. equal to unity. Table (1-5) show values of critical velocity ratio (m).

No	silt grade	CVR
1	light sandy silt, as in Upper Bari Do	1.0
2	coarse light sandy soil	1.1
3	sandy loam	1.2
4	coarse silt or debris of hard soil	1.3
5	silt of river indus	0.77
6	silt of river nile	0.68

CVR--CRITICAL VELOCITY RATIO.

Design of channels by kennedy's theory

The design procedure will depend whther the bed slope (S) is given or the (B/D) ratio is given. The center water commission, new Delhiloy (B/D) ratio for canals carrying discharge ranging from 0.3 to 300 m^3/sec we can use a useful chart of this method or for canals up to adischarge of 15 m^3/s the following empirical formula is also somtimes used (D=0.5$\sqrt{B}$) for alluvia canal.

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Design procedure when the bed slope is given (given Q ,m,n and S).

Steps:

1. assume a trial value of the depth (h).

2. calculate the velocity from ($v=0.5m\ h^{0.64}$).

3. determine the cross sectional area($A=Q/V$)

4. assume aside slope of (1H:2V), (1:0.5) ,and determine the width B from the relation. eqs, $A=BD+0.5D^2$

5. calculate the actual mean velocity (v) from kutter's or mannings eqs.

IF the value of (v) is nearly the same as that found from kennedy's eq. the assumed depth is correct . if not, the procedure is repeated after assuming anther value of (h) till the two values of velovity are approximately equal.

Ex: Design achannel carrying adischarge of $30m^3$/sec with critical ratio andd mannings (n) equal to 1.0 and 0.0225 , respectively. The bed slope is equl to 1 in 5000.

Sol: kennedy's method

Assume h=2.0m

$V=0.55m\ h^{0.64} = 0.55x1x(2)^{0.64} = 0.857m/s$

$A=Q/V=30/0.857=35.01m^2$

For a trapezoidal canal with side slope 1H:2V , $A=bh+h^2/2$

$35.01=2b+2 \longrightarrow b=16.51m$

$R=A/P$, $P=16.51+2x2\sqrt{1+0.5^2} = 1.67m$

$V=1/n\ R^{2/3}\ S^{1/2} =0.885m/s$

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Since the velocities obtained from the kennedy's equation and manning's equation are appreciably different , assume h=2.25m ,

V=0.924 m/s , $A=32.47m^2$

B= 13.31m , R=1.77m , V= 0.92m/s ≈ 0.924m/s

Design procedure when the B/D ratio is given (given Q,M,N and B/D ration)

1. calculate the area (A) in terms of (D) as followed

$A=BD+0.5D^2=D^2(B/D+0.5)$

Or $A=D^2(X+0.5)$

Where → X = B/D ratio

2. the cotinuity eq . and substitute kenndys eq . for the velocity.
Thuse → $Q=V.\ A=D^2(X+0.5)\ (0.55m\ D^{0.64})$

3. calculate the value of (D) from the above eq.

4. determine thr bed width B=XD

5. compute $\mathrm{R} = \mathrm{A}/\mathrm{P}$

6. determine the velocity (V)

7. compute the slope from Kutter's or Manning's eq.

The design of non-alluvial is usually don by Chezy's equation or Manning's formula.

Chezy's equation $V = C\sqrt{R\ S}$

Where C is Chezy's coefficient. The value of Chezy's coefficient is usually determined from Bazin's equation.

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$$C = \frac{87}{1 + \frac{K}{\sqrt{R}}}$$

Where K is Bazin's coefficient, which depends upon the surface of the channel. R is hydraulic radius and S is the longitudinal slope.

Channel in which silting problems are anticipated should be designed to have some minimum permissible velocity or the non-silting velocity. However, this velocity is very uncertain and can be determined only by advanced theories of sediments transport. The minimum velocity of 0-5 m/s is usually taken in other words, the velocity should on be le than 5.5 m/s.

Procedure the following procedure is used for design of non-alluvial channel by Manning's formula. Similar procedure can be used for design by Chezy's equation.

Given the discharge (Q), the maximum permissible velocity (*V).* Manning's *N.* bed slope*(S)* and the side slope (r : 1) are given or have been assumed.

Steps:

1. Determine the area of cross-section from the continuity equation:

   $Q = AV$ Or $A = Q/V$

2. *Determine hydraulic radius R from the Manning formula.*

$$V = \frac{1}{N} R^{2/3} \ S^{1/2} \quad or \quad R = \left(\frac{VN}{S^{1/2}}\right)^{3/2}$$

3. Determine the wetted perimeter from the relation. P = A/R
4. Determine the depth D and bed width B from the values of A and P obtained from Eqs. (a) and (c) by solving the equations below.

$$(B + rD)\ D = A$$

$$B + \left(2\sqrt{1 + r^2}\right)\ D = p$$

Example

Design an irrigation channel in a non-alluvial material to carry a discharge of 15 cumecs when the maximum permissible velocity is 0.8 m/s. Assume bed slope = 1 in 4000, side slope 1:1 and Manning's N = 0.025

Solution A = Q/V = 15/0.8 = 18.75 m^2-

$$R = \left(\frac{VN}{S^{1/2}}\right)^{3/2} = 1.42\ m$$

$$P = \frac{A}{R} = 18.75/1.42 = 13.20\ m$$

Now $(B + D)\ D = 18.75$

And $B + \left(2h\sqrt{1 + 2^2}\right) D = 13.20 \quad or \quad B + 2.828\ D = 13.20$

Substituting the value of B from Eq. (b) in Eq. (a).

$[(13.20 - 2.828\ D) + D]\ D = 18.75$ Or D=1.95 m

Now $B = 13.20 - 2.828 \times 1.95 = 7.69\ m$

Example

An earthen channel in good condition carries a discharge of 10.0 cumecs

with a mean velocity of 0.7 m/s. determine the bed slope. Assume the bottom width as twice the depth. Take Bazin's coefficient as 1.30 and side slope as 1.5:1

B=2D

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Solution

A = Q/V *= 10/0.7 =14.30 m²*

Now $(2DB + 1.5\ D)D = A = 14.30 \quad or \quad 3.5D^2 = 14.30$

Or $D = 2.02\ m. B = 4.04\ m$

Now $P = B + \left(2\sqrt{1 + (1.5)^2}\right) \quad d = 4.04 + 728 = 11.32\ m$

$R = A/P \qquad = 14.30/11.32 = 1.26\ m$

$$C = \frac{87}{1 + K\sqrt{R}} = \frac{87}{1 + 1.30\sqrt{1.26}} = 40.32$$

Now $V = C\sqrt{RS}$

Or $0.7 = 40.34\ \sqrt{1.26 \times S} \quad or\ \ S = 1\ in\ 4185.$