UNIT - II
CANALS

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Syllabus ⇒ classification, design of non-erodible canals, methods of economic section and maximum permissible velocity, economics of canal lining, design of erodible canals - kennedy's silt theory & lacey's regime theory, balancing depth of cutting.

Classification →

A canal is an artificial channel, generally trapezoidal in shape constructed on the ground to carry water to the fields either from the river (or) from a tank (or) Reservoir.

Canals can be classified in following ways

(a) classification based on the nature of source of supply

(1) permanent canal (2) Inundation canal.

* A canal is said to be permanent when it is fed by a permenent source of supply.
* Inundation canals usually draw their supplies from rivers whenever there is a high stage in the river.

(b) classification based on the function of the canal

(1) Irrigation canal (2) Carrier canal (3) feeder canal
(4) Navigation canal (5) power canal

→ Irrigation canal carries water to the agricultural fields.
→ A carrier canal besides doing irrigation, carries water for another canal.
→ A feeder canal is constructed with the idea of feeding two (or) more canals.

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(c) classification based on financial output →

(1) productive canal. (2) protective canal.

→ productive canals are those which yield a net revenue to the nation after full development of irrigation in the area.

→ protective canal is a sort of relief work to constructed with the idea of protecting a particular area from famine.

b) Classification based on boundary suface of the canal →

Based on the type of boundary suface, canals may be of the following type

(1) Alluvial canal (2) Non-Alluvial Canal

(3) Rigid boundary canal. [lined canals].

c) Classification based on the dischaige and its relative importance in a given network of canals →

1. Main canal 2. Branch canal
3. Major distributoy 4. Minor distributory
5. Water couse.

→ Main canal generally carries water directly from the river (or) Reservoir. such a canal carries hebvy supplies ind is not used for direct irrigation. these are act is water carriers to feed supplies to branch canals ind Major distributaries.

→ Branch canals are the branches of the main canal n either direction taking off at regular intervals. these canals are uually feeder channels for major & ninor distributaries. they usually cary a discharge of 5 cumecs

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→ Major distributaries usually called Rajbha. Takeoff from branch canal. They are real irrigation channels their discharge varies from 1/4 to 5 cumecs.

→ Minor distributaries (or) Minor take off from branch canals (or) from distributaries. Their discharge usually less than 1/4 cumecs.

→ A water course (or) field channel is a small channe which ultimately feeds the water to irrigation fields.

(f) Classification based on canal alignment →

According to the alignement, a canal may be classifie as (1) contour canal (2) watershed canal

(3) side slope canal.

→ Ridge canal (or) watershed canal is aligned along a watershed and runs for most of its length on a watershed.

→ Contour canal aligned nearly parallel the contours o, the area

→ Side slope canal is a channel aligned roughly at right angle to the contour of the country and is neither on the watershed nor in the valley.

Design of Non-erodible (or) Non-Alluvial channe

Non-alluvial channels are those which flow through non-alluvial soils such as loam, clay, moora and other hard soils, including boulders and rocks.

In the non alluvial soils, water is relatively clear due to which there is no problem of silting

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these channels are therefore considered as stable channels. Non-alluvial channels are designed on the basis of maximum permissible velocity that could be permitted in the channel without causing any scour either in the bed (or) in the sides.

Values of permissible velocities.

	Type of Bed Material	Permissible velocity (m/s)
1.	ordinary soil	0.6 - 0.9
2.	loam; lean clay	0.4 - 1.0
3.	Ordinary clay	0.5 - 1.2
4.	Heavy clay	0.6 - 1.6
5.	light loose Sand	0.3 - 0.6
6.	Hardsoil & Moorum	1.0 - 1.2
7.	Gravel	1.2 - 1.5
8	Boulders	1.5 - 1.8
9	Soft Rock	1.8 - 2.4
10	Hard rock	2.5 - 5.

Side slopes → The side slopes (H:V) of channels in ordinary soils, including clay, are generally kept as 1:1 in cutting and 1.5:1 in filling. However in grit (or gravel), soft rock, and hard rock the side slopes are 0.5:1, 0.25:1 & 0.125:1 respectively though the sides may be kept even vertical in very hard rocks.

Flow equations →

The design of non-alluvial channels is done on the basis of the following two flow eq

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(i) Chezy's formala (ii) Manning's formula.

Chezy's formula →

$$V = C\sqrt{RS}.$$

Where C is chezy's coefficient usually determined from the following eq, by bazin

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

Where

K - Bazin's coefficient for earth channels = 1·2 - 1·4 {good condition}

for earth channels = 1·7 - 1·8 {poor condition}

Manning's formula →

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

Where

N - Manning's coefficient.

Values of N

Type of surface	Value of N
1. Earth channel; clean straight & uniform	0.016 - 0.020.
2. Earth channel clean but weathered	0.018 - 0.025

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Design procedure

for a channel design, the discharge Q and bed slope s are generally known. The value of max permissible velocity and side slopes (r:1) are choosen on the basis of type of soil through which the channel has to flow.

Step 1: Determine the Area of c/s from the continuity eq/

$$A = Q/V \Rightarrow \{ \because \text{from } Q = AV \}.$$

Step 2: Determine hydraulic mean radius from Mannings formula

$$R = \left[\frac{VN}{S^{1/2}}\right]^{3/2}.$$

Step 3: Determine wetted perimeter (P) from the Relation

$$P = A/R.$$

Step 4: for a trapezoidal channel with sideslopes (r:1), the area of cross-section (A) & wetted perimeter (P) are given by

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

$$P = B + 2(D\sqrt{1+r^2}).$$

Note → for the most efficient channel trapezoidal section having side slopes of $1/\sqrt{3}$: 1 (H : V) & $R = D/2$.

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lining of Irrigation channels →

Necessity → lining of canal is necessary for

(i) to minimise the seepage losses in canal
(ii) to increase the discharge in canal section by increasing the velocity.
(iii) to prevent erosion of bed and side due to high velocities.
(iv) to retard the growth of weeds, and
(v) to reduce maintanance of canal.

Advantages of lining →

→ The lining of canals prevents seepage loss and thus more area can be irrigated by the water so saved. The cost of irrigation is therefore reduced.
→ The lining of canal is an important anti-water logging measure as it reduces seepage to the adjoining land.
→ The lining provides smooth surfaces. The rugosity coefficient, therefore decreases.
→ The increased velocity minimises the losses due to evaporatic
→ The increased velocity helps to provide a narrow c/s for lined channels.
→ Higher velocity prevents silting of channel.
→ lining makes the banks more stable in light textured soil
→ lining prevents (or) reduces weed growth.
→ canal lining assures economical water distribution.

Types of lining →

1. cement concrete lining
2. shotcrete lining
3. precast concrete lining
4. cement mortar lining
5. Brick lining
6. stone blocks, (or) undressed ston lining
7. Asphaltic lining.
8. soil cement lining.
9. clay puddle lining
10. Road oil lining.

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Economics of Canal lining →

At times, the choice of canal lining is to be done on financial considerations besides the technical feasibility. For determining its economic viability, an analysis of benefits from canal lining has to be worked out in terms of money. The benefits from lining should be greater than extra cost to be incurred on lining.

Calculation of benefit →

The major benefit then can be readily assessed in terms of money is from the saving of seepage water which would have been lost from unlined channel. this water when supplied to farmers will yield revenue.

let q cumecs be the water saved in the lined reach and R_1 rupees be the cost of water per cumec. then the total saving $= q \cdot R_1$ rupees.

let p be the percentage saving in annual maintanence cost which is rupees R_2 for unlined channel. then the saving in annual maintanance cost $= PR_2$ rupees.

total benefit (B) per year $= (qR_1 + PR_2)$ rupees.

Annual cost of extra expenditure on lining →

Annual cost of extra expenditure on lining $\Rightarrow$

$$C \times i(i+1)^N \left[(1+i)^N - 1\right]^{-1}.$$

$\therefore$ Benefit cost ratio (B.C.R) is

$$BCR = \frac{(qR_1 + PR_2)\left[(1+i)^N - 1\right]}{C \times i (1+i)^N}$$

$$= \frac{B\left[(1+i)^N - 1\right]}{C\, i (1+i)^N}$$

If rate of interest is 8% per annum $i = 0.08$.

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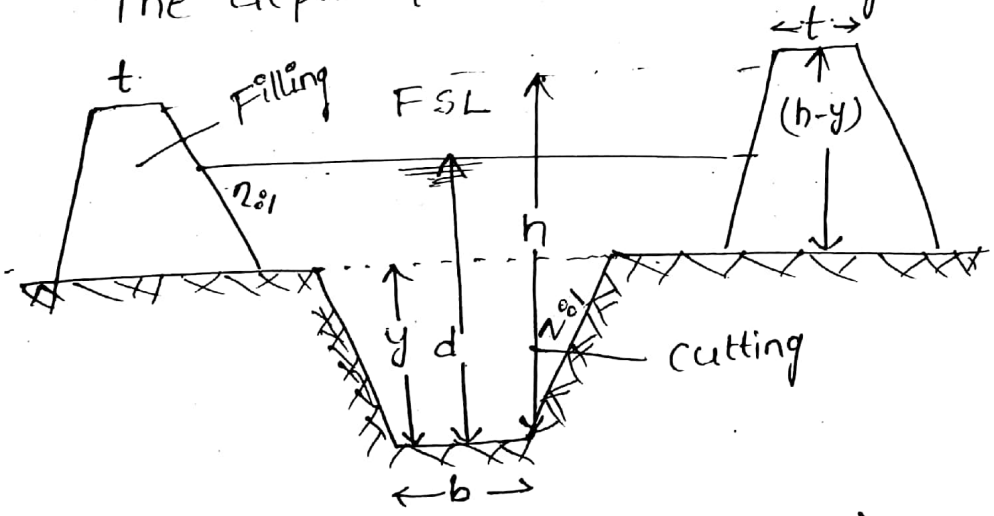
For the project justification, the benefit cost ratio should be greater than 1.

Balancing depth of cutting & filling →

A canal section will be economical when the earth work involved at a particular section has an equal amount of cut & fill. Usually a canal section has a part in cutting and part in filling as shown in fig. If the amount of cut is equal to the amount of fill, it has to be paid for once only.

the necessity of a borrow pit (or) soil bank is entirely avoided. for a given cross-section there is always only one depth of cutting for which the cutting & filling will be equal.

The depth is known as balancing depth.



$\therefore$ Area of the cut = $y(b+zy)$

$\simeq by+zy^2$

Area of filling = $2\left[(h-y)t+n(h-y)^2\right]$.

*Note → A canal is usually constructed with a side slope of 1:1 in cutting & a slope 1.5:1 in filling.

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Design of Erodible (or) Alluvial canals by using Kennedy's & lacey's design principle →

The channel (or) canal which takes off from a river has to draw a fair share of silt flowing in the river. this silt is carried eaither in suspension or along the bed of the channel.

The silt load carried by the channel imposes a difficult problem in a channel design in alluvial soils. If the sides and bed of a channel are eroded away, the C/s increases and besides other damages because of scour, its full supply depth decreases; it can therefore command much less area A velocity which will just keep the silt in suspension without scouring the channel is known as non-silting & non-scouring velocity.

Many investigations have worked on various existing channels towards the design of Non-silting, Non-scouring channel section.

Notable amongst them are Mr R.G. kennedy & Mr. Gerald lacey as Kennedy's theory and Lacey's theory respectively.

For the design of an irrigation channel, the design discharge Q, and the surface and soil properties such as rugosity coefficient N and silt factor f are known. The problem consists in determination of the four unknowns

(i) Area of c/s (A)

(ii). Hydraulic mean depth (R).

(iii) Velocity of flow (V)

(iv) Bed slope (S)

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Kennedy's theory →

* Kennedy selected a number of sites on upper Bari doab canal system, one of the oldest in punjab for carrying out investigations about velocity & depth of the channel.

* The following water has to counteract some amoun of friction against the bed of the canal. This gives rise to vertical eddies rising up gently to the Surface.

* These eddies are responsible for keeping most of the silt in suspension.

* He also gave a relation b/w critical velocity to the depth of flowing water.

$$\boxed{V_c \text{ (or) } V_0 = 0.55\, m\, d^{0.64}} \approx \boxed{V_c = CD^n}$$

m = critical velocity ratio
= 1.1 to 1.2 for coarse sand,
= 0.8-0.9 for fine sand,

$$\therefore m = CVR = \frac{\text{critical velocity for the area}}{\text{Critical velocity for upper bari doab canal system}}$$

$$C = \frac{\left[\frac{1}{n} + \left(23 + \frac{0.00155}{S}\right)\right]}{\left[1 + \left(23 + \frac{0.00155}{S}\right) n/\sqrt{R}\right]}$$

$$V = C\sqrt{RS}$$

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Value of C.

Types of material	'C'
light sandy silt	0.53
coaser light silt	0.59
sandy loam	0.65
Coarse silt	0.70.

Value of m

Type of silt	Value of m
light sandy silt in the rivers of Northen India	1.00
Somewhat coaser light sandy silt	1.10
Sandy, Joamy silt	1.20
Rather coaser silt (or) debris of hard soil	1.30
silt of river Indu in sind	0.70

Fixation of longitudinal slope (S) of channel ⇒

Slope	B(m)	D(m)	B/D.
1 in 5000	7	0.68	10.8
1 in 4000	3.2	0.85	3.8
1 in 2000	1.5	1.41	1.07.

Fixation of B/D ratio ⇒

(a) Woods table for B/D ratio

(b) Emprical formula & table

for channels having Q < 15 cumecs

$$D = 0.5\sqrt{B}.$$

for Q ≥ 15 cumecs follow the table

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Value of Water depth (D)

Discharge	Depth D cm)
15	1.7
30	1.8
75	2.3
150	2.6
300	3.0

(c) Recommendation of CWPC for B/D ratio →

$$B/D = r = [15 + 6.44\sqrt{Q}]^{0.382}$$

for eg Q = 14 cumecs

$$B/D = [15 + 6.44 \times 14]^{0.382} \simeq 5.9.$$

Drawbacks in Kennedy's theory →

1. Kennedy did not notice the importance of B/D ratio.
2. He aimed to find out only the average regime conditions for the design of a channel.
3. No account was taken of silt concentration and bed load, and the complex silt carrying phenomenon was incorporated in a single factor m.
4. Silt grade and silt charge were not defined.
5. Kennedy did not give any slope equation.
6. Kennedy used Kutter's equation for the determination of the mean velocity and therefore, the limitations of Kutter's eq, got incorporated in Kennedys theory of channel design.

Lacey's Regime theory →

Regime channel → lacey defined regime channel as a stable channel transporting a regime silt charge. A channel will be in regime if it flows in unlimited incoherent alluvium of the same character as that transported and the silt grade & silt charge are constant.

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Incoherent alluvium → it is a soil composed of loose granular graded material which can be scoured with the same rate with which it is deposited.

Regime silt charge → it is the min transported load consistant with fully active bed.

Regime silt grade → this indicates the gradation b/w the small and the big particles. It should not be taken to mean the average mean diameter of a particle.

Regime conditions → A channel is said to be in regime when the following conditions are satisfied.

1. The channel is flowing in unlimited incoherent alluvium of the same character as that transported.
2. silt grade and silt charge are constant.
3. Discharge is constant.

nitial regime → Initial regime is the state of channel that hay formed its section only and yet not secured the longitudinal slope.

inal regime → To attain the final regime the channel forms its section first before the final slope. The channel fter attaining its section and longitudinal slope will be said to be in final regime.

ermanent regime → When a channel is protected on the bed and side with some kind of protecting material, the channel section cannt be scoured up & so there is no possibility of change of section (or) longitudinal slope.

$\therefore$ silt factor $(f) = 1.76\sqrt{m}$

m = mean particle size, (mm).

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→ $V = \left[\frac{QF^2}{140}\right]^{1/6}$ (velocity).

→ $P = 4.75\sqrt{Q}$ (Wetted perimeter)

→ $R = 5/2\left[V^2/f\right]$ (hydraulic radius)

→ $S = \frac{f^{5/3}}{3340 \cdot Q^{1/6}}$ (Slope)

Values of f.

Type of soil	value of f
1. fine silt	0.50 – 0.70
2. Medium silt	0.85
3. standard silt	1.00
4. medium sand	1.25
5. coarse sand	1.50.

Defects in lacey's theory →

1. The theory doesn't give a clear description of physical aspects of the problem.
2. It does not define what actually governs the characteristics of an alluvial channel
3. lacey's eq do not include a concentration of silt as variable
4. lacey did not properly define the silt grade and silt charge.
5. lacey introduced semi ellipse as ideal shape of a regime channel which is not correct.

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Kennedy's theory

→ It states that the silt carried by the following water is kept in suspension by the vertical component of eddies which are generated from the bed of the channel

→ Relation b/w V & D
→ critical velocity ratio 'm' is introduced to make the eq applicable to diff channels with diff. silt grades.
→ Kutters eq is used for finding the mean velocity.
→ this theory gives no eq for bed slope.
→ In this theory, the design is based on trial & error method.

Lacey's theory.

→ It states that the silt carried by the following water is kept in suspension by the vertical component of eddies which are generated from the entire wetted perimeter of the channel.

→ Relation b/w V & R.
→ Silt factor 'f' is introduced to make the eq applicable to diff channels with diff silt grades.
→ this theory given an eq for finding the mean velocity.
→ this theory gives an eq for bed slope
→ this theory does not in valve trial and error method.

Comparison of Kennedy's and Lacey's theory →

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