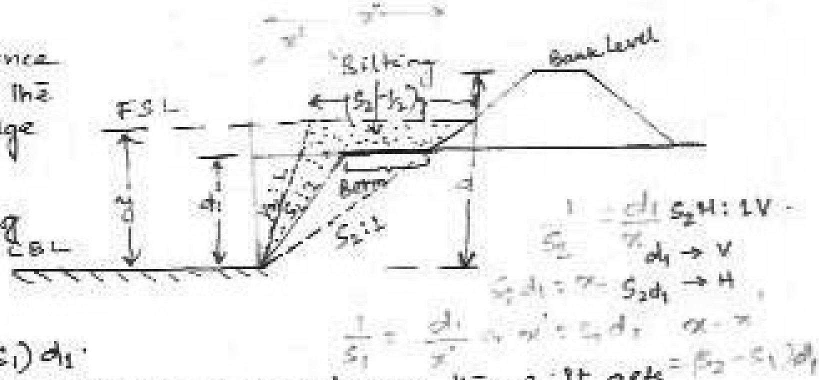
2. Berms



- Berm is the horizontal distance left at ground level between the toe of the bank & the top edge of cutting.
- If $S_1:1$ is the slope in cutting and $S_2:1$ is the slope on filling, then the initial berm width, $(BW)_i = (S_2 - S_1)d_1$
- After the water flows in the channel for some time, the silt gets deposited on the sides giving them a slope of $\frac{1}{2}:1$. The position of berm thus changes from ground level to FSL & its width becomes equal to $(S_2 - \frac{1}{2})y$ & if $S_2 = 1\frac{1}{2}$ then $B.W = y$ i.e; equal to the depth of water in the canal.

- **Purposes of Berms**
  - → Serves as good lining for reducing losses, leakage & consequent breaches etc.
  - → Helps to attain regime conditions (as they provide wider waterway)
  - → Protect banks from erosion due to wave action.
  - → Provide scope for future widening of canals.
  - → Used as borrow pits for excavating soil to be used for filling.
  - → Reduces breaching because saturation line comes more within the body of embankment.

3. Free board

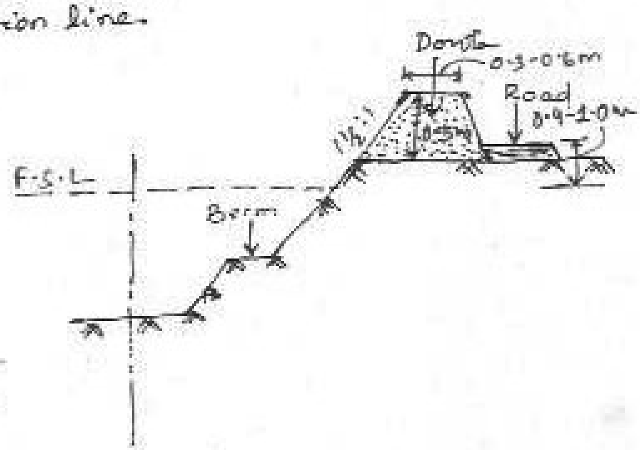
- Margin between FSL & bank level is known as free board.
- Margin between the size of the channel.
- The amount of freeboard depend upon the size of the channel. More height of freeboard should be adopted for higher discharge.

4. Banks

- Primary purpose of banks is to retain water. They can be used as means of communication and as inspection paths.
- They should be wide enough, so that a minimum cover of 0.5 m is available above the saturation line.

5. Service Roads

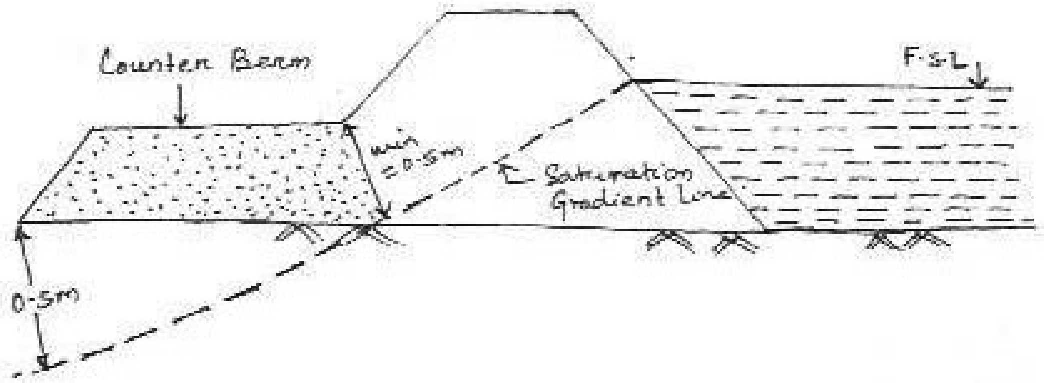
- Service roads are provided on canals for inspection purposes and may simultaneously serve as the means of communication in remote areas.
- They are provided 0.4m to 1.0 m above FSL depending upon the size of the channel.



Dowlas (e/w in filling)

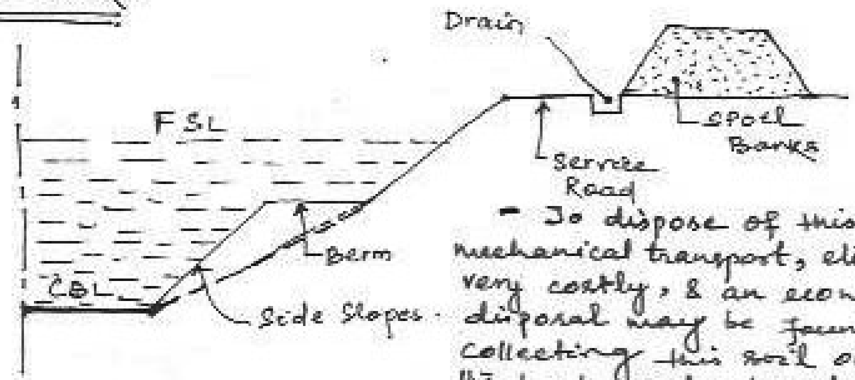
- As a measure of safety in driving, dowlas 0.3m high & 0.3 – 0.6 m wide at top, with side slopes of $1\frac{1}{2}:1$ to $2:1$, are provided along the banks.
- They also help in preventing slope erosion due to rains, etc.

6. Back Berm or Counter Berm



Even after providing sufficient section f. bank embankment, the saturation gradient line may cut the d/s end of the bank. In such a case, the saturation line can be kept covered atleast by 0.5 m with the help of counter berms.

7. Spoil Banks



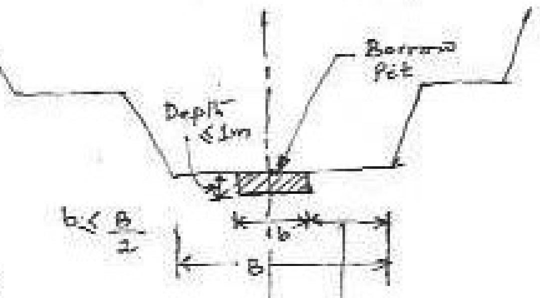
- To dispose of this earth by mechanical transport, etc. may become very costly, & an economical mode of its disposal may be found in form of collecting this soil on the edge of the bank embankment itself.

When the $(E/W)_{excavation} > (E/W)_{filling}$; the extra earth has to be disposed of economically.

The soil, is therefore, deposited in such a case, in the form of heaps on both banks or only on one bank.

8. Borrow Pits

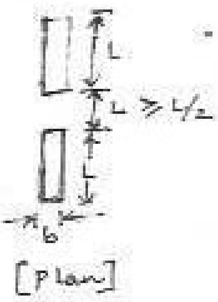
- When the $(E/W)_{filling} > (E/W)_{excavation}$ the earth has to be brought from somewhere. The pits, which are dug for bringing earth, are known as borrow pits.



[Elevation] c/s

- External Borrow Pits :- If such pits are excavated outside the channel. They are generally not preferred.
- Internal Borrow Pits :- If such pits are excavated somewhere within the channel.
- The borrow pits should start from a point at a distance more than 5m from the toe for small channels, and 10 m for large channels.
- Width of these pits b, should be less than half the width of the canal B, and

- Longitudinally, these pits should not run continuous, but a minimum space of $\frac{L}{2}$ should be left between two consecutive pits (where L is the length of one pit.)



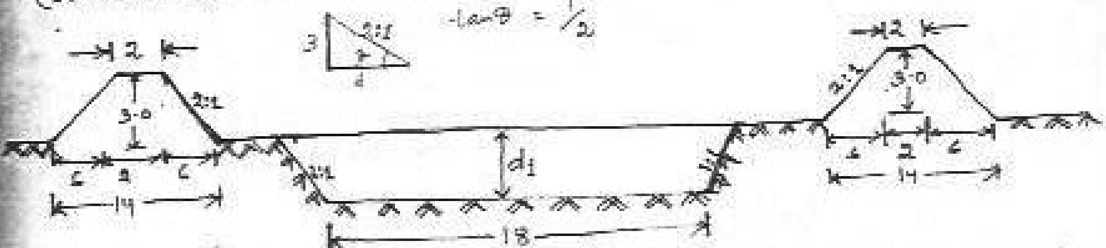
Balancing Depth for Excavating Canals.

- Maximum economy can be achieved in canal construction, if the earthwork in excavation = earthwork in filling.
  Such a case is possible when a canal is constructed partly in filling and partly in cutting, which mostly happens in practical life.
- In such cases the need for spoil banks & borrow pit can be eliminated.

★ For a given c/s of a channel, there can be only one depth, for which such a balance between cutting & filling will occur. This depth is known as "Balancing Depth".

example :-
Calculate the balancing depth for a channel section having a bed width equal to 18m & side slopes of 1:1 in cutting & 2:1 in filling. The bank embankments are kept 3.0 m higher than ground level (berm level) & crest width of banks is kept as 2.0 m.

2H : 1V
1H : 1V



Let d_1 be the balancing depth, i.e., the depth for which excavation & filling becomes equal.

$$\text{Area of cutting} = \frac{1}{2}h(a+b) = \frac{1}{2} \times d_1 (18 + 18 + 2d_1)$$

$$= d_1(18 + d_1)\ \text{sq.m.}\ (m^2)$$

$$\text{Area of filling} = 2\left[\frac{1}{2} \times 3(2+14)\right] = 48\ m^2.$$

Equating cutting & filling we get,

$$(18 + d_1)d_1 = 48$$

$$\text{or}\quad d_1^2 + 18d_1 - 48 = 0.$$

$$d_1 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-18 \pm \sqrt{324 + 192}}{2}$$

$$\text{or}\quad d_1 = \frac{-18 \pm 22.7}{2}$$; Ignoring unfeasible -ve sign we get,

$$d_1 = \frac{-18 + 22.7}{2} = \frac{4.7}{2} = 2.35\,m$$

Balancing Depth = **2.35 m.** Ans.

Chapter-4.

General

- Irrigated area is constantly & continuously being increased.
- Expenditure of about Rs 1,15,000 crores has been incurred in our country on major & medium irrigation projects since independence and upto the end of 9th 5-year plan (1997-2002).
- Irrigation water is a costly commodity.
- Most canal constructed in India, are unlined and large part of costly irrigation water is lost in percolation & absorption as seepage loss.
- 25-50% of the water is lost in seepage.
- Seepage can be avoided or minimised by lining the irrigation canals.

By lining the canal, we mean that the earthen surface of the channel is lined with a stable (inerodible) lining surface, such as concrete, tiles, asphalt etc.

Seepage losses can be reduced to 2-5% of their original values by lining the canals.

ADVANTAGES OF LINING

(1) Seepage Control :-

A lined canal costs about 2 to 2½ times as much as an unlined canal, but where seepage is heavy, the saving of costly irrigation water may itself be sufficiently fully justify the capital expenditure on lining.

Heavy seepage losses in canals would necessitate the construction of larger reservoirs & bigger dams. Prevention of seepage by lining would, therefore, reduce their impounding capacity, and hence, lower the construction costs of these works.

(2) Prevention of Water-logging.

Uncontrolled seepage through unlined canals often raises the water-table in the surrounding fields upto or near to the ground level. This, in turn, brings up the alkali salts near to the ground surface, which soon renders the land unfit for cultivation. Such a land is usually called 'thur', and the phenomenon of rise of water table is known as water logging.

Lining of canals combined with land drainage schemes, helps to reclaim waterlogged areas.

(3) Increase in Channel Capacity.

Lining presents a smooth surface → Less resistance to flow of water → Velocity increase → more water is carried per second than in an unlined canal.

$$V = \frac{1}{n} R^{2/3} S^{1/2} \rightarrow \text{Manning's formula}$$

- Lining, therefore, increases channel capacity and consequently reduces the channel section.
Lined canal will require lesser dimension and hence lesser c/s.

(4) Increase in Commanded Area.
- A lined canal can be designed not only smaller in cross-section but also shorter in length.
- Steeper gradients can be provided because higher velocities are permissible (as the material is less erodible) and a shorter alignment can, therefore, be selected.
- On the other hand, flatter slopes can be provided without silting on a lined channel compared to those on an unlined canal.
It can, therefore, help to bring high areas under command.

(5) Reduction in Maintenance Costs.
- The up-keep of unlined canals involve huge recurring expenditure, generally charged under the head of account: A.R and M.O of the canal system (i.e; Annual repair & maintenance of canal system.)
- The expenditure may be required on:
(i) periodical removal of silt deposited on the bed & sides of canal sections;
(ii) minor repairs like plugging of cracks, cuts & uneven settlements of banks; and
(iii) removal of weeds & water plants.

(6) Elimination of Flood Dangers.
- An unlined canal founded on weaker foundation is always in dangers and a breach may occur at any time.
- Instances have occurred where small breaches in unlined canals resulted in washing away of considerable length of embankment - leading to flooding of certain areas & causing scarcity of irrigation water in others. A strong concrete lining removes all such ~~dangers~~ dangers.

FINANCIAL JUSTIFICATION AND
ECONOMICS OF CANAL LINING.

- In considering the economy of canal lining, it is necessary to evaluate the tangible (measured in terms of money) & additional benefits, and then to compare these with the cost of lining.
- Mathematically, expenditure on a project is justified if,
Resultant Annual Benefits > Annual costs (including interest on the capital expenditure)
i.e; Benefit cost Ratio > 1

- * The justification for lining the existing channel is different from that of constructing new lined channels in a new project.
- By adopting lining for new canals, a large no. of additional advantages are obtained.

- Smaller & possibly fewer canal structures
- lesser earth-work - handling
- lesser land acquisition
- lesser impounding reservoir capacities etc.
- Smaller canal sections.

JUSTIFICATION FOR LINING THE EXISTING CANALS.

(i) Annual Benefits.

(a) Irrigation water is sold to the cultivators at a certain rate.
Let this rate be Rs. R_1 per cumec.
If m cumecs of water is saved by lining the canal, annually, then money saved by lining = mR_1 rupees.

(b) Lining will also reduce maintenance cost. The average cost of annual upkeep of unlined canal can be worked out from previous records.
Let it be Rs. R_2; If p is the percentage fraction of the saving achieved in maintenance cost by lining the canal, then the amount saved = Rs. pR_2

$\therefore$ Total annual benefits $= mR_1 + pR_2$

(The value of p is generally taken as 0.4)

(ii) Annual Cost.

If the capital expenditure required on lining = Rs. C
And lining has a life of Y years (say).

$\therefore$ Annual Depreciation charges = Rs. $\frac{C}{Y}$

If r percent is the rate of annual simple interest
Capital of Rs C would earn annually $C\left(\frac{r}{100}\right)$ rupees as interest charges.
Avg. Annual interest cost may be taken as Rs $\frac{C}{2}\left(\frac{r}{100}\right)$

$\therefore$ Total annual cost of lining $= \frac{C}{Y} + \frac{C}{2}\left(\frac{r}{100}\right)$

$$\text{Benefit Cost Ratio} = \frac{\text{Annual Benefits}}{\text{Annual Costs}}$$

$$= \left[\frac{mR_1 + pR_2}{\frac{C}{Y} + \frac{C}{2}\left(\frac{r}{100}\right)}\right]$$

$$\text{B/C Ratio} = \left[\frac{mR_1 + 0.4R_2}{\frac{C}{Y} + \frac{C}{2}\left(\frac{r}{100}\right)}\right] \quad (\text{if } p = 0.4)$$

For project justification, benefit cost ratio must be greater than unity.

Justification in lining an existing unlined canals.

Q. An existing unlined channel is having the following dimensions:

Width of the bottom = 1.52 m
Side slopes = $1\frac{1}{2}:1$
Depth of flow = 0.91 m
Bed slope = 0.0006

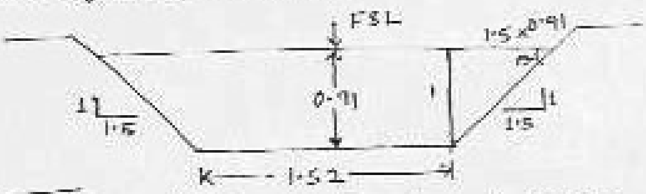
It is proposed to line this channel for the same discharging capacity. Find out the dimensions of the lined channel & work out the economics of the concrete lining, if following data are given:

Length of irrigation season = 150 days.
Saving in seepage loss by lining the canal = 1.5 % per km.
Cost of water = Rs 150 per ha.m.
Cost of concrete lining = Rs 16 per sq.m.
Cost of reshaping & trimming canal = Rs 4.60 per sq.m
Life of lining = 40 years.
Interest Rate = 7 %.
Annual maintenance and operational cost (per km per year)
for unlined canals in earth = Rs 1000.00
and for concrete lined canals = Rs 200.00
Other additional benefits = Rs 350.00
Assume any other necessary data, if not given.

Solution:-

Discharge capacity of existing unlined canal.

$\sin\theta = \frac{0.91}{\sqrt{(\frac{3}{2})^2+1^2}}$



Existing unlined canal section.

✓Sloping side $= \sqrt{(0.91)^2+(1.5\times0.91)^2}$

$= 0.91\sqrt{(1)^2+(1.5)^2} = 1.8\times0.91 = 1.64\,m$

Wetted Perimeter $= 1.52+(2\times1.64) = 4.8\,m$

Area (A) $= \frac{1}{2}\times0.91\,[1.52+1.52+1.365+1.365]$

$= \frac{1}{2}\times0.91\times2\,[1.52+1.365]$

$= 2.62\,m^2$.

Hydraulic Radius, $R = \frac{A}{P} = \frac{2.62}{4.8} = 0.546\,m$

By Manning's formulas. Assume n for unlined channel = 0.025.

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

or $V = \frac{1}{0.025}(0.546)^{2/3}(0.0006)^{1/2}$ (for unlined canal, n (assumed) = 0.025)

or $V = 0.654\,ms^{-1}$

$Q = A \cdot V = 2.62 \times 0.654 = 1.713$ cumecs.

In a lined channel, the water will flow more rapidly & depth of flow will be less for the same discharge.

Assume n for lined channel $= 0.014$

$A = y(1.52 + 1.5y)$

$A = \frac{1}{2} \cdot y \cdot (1.52 + 1.52 + 2 \times 1.5y)$

Discharge through lined channel is given by,

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

or $$Q = \frac{1}{n} \times A \cdot \left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

or $$1.713 = \frac{1}{0.014} \frac{(1.52y + 1.5y^2)^{5/3}}{[1.52 + 2 \times 1.8y]^{2/3}} \times (0.0006)^{1/2}$$

$P = 1.52 + 2\sqrt{y^2 + (1.5y)^2}$
$= 1.52 + 2\sqrt{3.25}\,y$
$= [1.52 + 2 \times 1.8y]$

or $$1.713 = \frac{1}{0.014} \times \frac{2.45}{100} \left[\frac{(1.52y + 1.5y^2)^{5/3}}{(1.52 + 3.6y)^{2/3}}\right]$$

or $$\frac{1.713 \times 0.014 \times 100}{2.45} = \frac{(1.52y + 1.5y^2)^{5/3}}{(1.52 + 3.6y)^{2/3}}$$

Solving the above eqn by hit & trial, we get

$$0.98 = \frac{(1.52y + 1.5y^2)^{5/3}}{(1.52 + 3.6y)^{2/3}}$$

$$y = 0.67\text{m}$$

If we use 0.5m free board, then perimeter of lining is

Total depth $(y) = (0.67 + 0.5)\text{m} = 1.17\text{m}$

$P = 1.52 + 2 \times \sqrt{(1)^2 + (1.5)^2} \times 1.17 = 5.74$ m.

Perimeter per km of lined channel $= 5.74 \times 1$ Km
$= 5.74 \times 1000\text{ m} = 5740\text{ m}^2$.

(b) Annual Benefits.

Seasonal flow.

Discharge in the channel $= 1.713$ cumecs $= 1.713\ m^3/s$

1 cumec (m^3/s) flowing for 150 days $= (1 \times 150 \times 24 \times 60 \times 60)\ m^3$

1.713 cumecs flowing for 150 days 1 ha $= 10^4 m^2$

Total quantity of water in an irrigation season $= (1.713 \times 3600 \times 24 \times 150)\ m^3$.

$$= \frac{1.713 \times 3600 \times 3600}{10^4} = 2220 \text{ ha-m}.$$

∴ Seasonal flow $= 2220$ ha-m.

Saving in seasonal seepage loss per km $= 1.5\%$ of flow

$$= \frac{1.5 \times 2220}{100} = 33.3 \text{ ha-m}$$ (Saving by lining of canal). In terms of vol^m of water

Annual Money saved in seepage loss per km

$= 33.3 \times$ Rs 150 $=$ Rs 4995 (∵ cost of water = Rs 150 per ha-m) (m × Rs; cost of water/ha-m; In terms of money.)

Annual savings in maintenance charges (per km)

$=$ Rs 1000 $-$ Rs 200 $=$ Rs 800

Other additional annual benefits $=$ Rs 350 (given)

Total annual benefits per Km = 4993 + 900 + 350

= Rs 6145.

(ii) Annual Cost.

Perimeter of lining = 5740 m^2 per km.

The cost of lining per km of channel @ Rs 16 per sq.m

= Rs 16 × 5740 = Rs 91,840 = C

Life of lining = 40 years = Y

Annual Depreciation charges = $\frac{C}{Y} = \frac{91,840}{40}$ = Rs 2296.

Avg. Annual interest charges = $\frac{1}{2} \times C \left(\frac{r}{100}\right)$

$= \frac{1}{2} \times 91,840 \times \frac{7}{100}$ = Rs 3214.

Total Annual Cost per km = (2296 + 3214) = Rs 5510.

Benefit – Cost Ratio = $\frac{\text{Annual Benefits per km}}{\text{Annual cost per Km}}$

$= \frac{\text{Rs } 6145}{\text{Rs } 5510} = 1.11$

Since the benefit-cost ratio is greater than unity, the lining is justified.

Ans.

DESIGN OF LINED IRRIGATION CHANNELS.

- Irrigation canals should be aligned, so that the velocity of flow is uniform under all conditions, and so that the water reaches the irrigated area at an sufficient elevation to ensure even & economical distribution.
- High velocities of flow can be permitted by taking the advantage of hard wearing surface, so as to ensure a hydraulically efficient channel. [Maximum Area with minimum Wetted perimeter].

Channel cross-sections.

Two types of channel sections are adopted i.e.

(i) Triangular channel section for smaller discharges. (Triangular channel section with rounded edges or apex).

Let Central depth = radius of circle = y

Area $= 2\pi y^2 \frac{\theta}{2\pi} + 2 \times \frac{1}{2} y \times y \cot\theta$

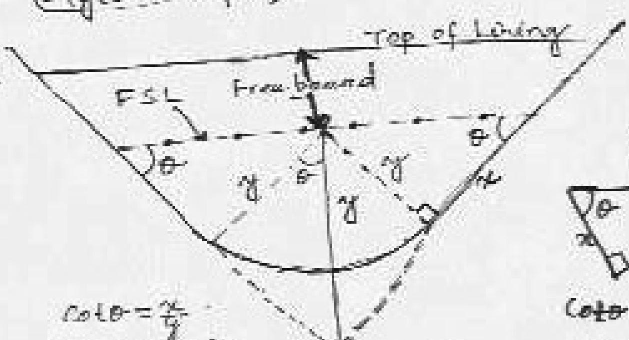
$= \frac{\pi y^2 \theta}{\pi} + y^2 \cot\theta$

$= y^2 [\theta + \cot\theta]$

Perimeter $= 2 \times 2\pi y \times \frac{\theta}{2\pi} + 2y\cot\theta$

$= 2y\theta + 2y\cot\theta$

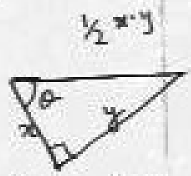
$= 2y(\theta + \cot\theta)$



$\cot\theta = \frac{x}{y}$

or $x = y\cot\theta$

[Triangular Section]



$\cot\theta = \frac{x}{y}$

$x = y\cot\theta$.

Hydraulic mean depth = $\frac{A}{P} = \frac{y^2[\theta + \cot\theta]}{2y[\theta + \cot\theta]} = \frac{y}{2}$.

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

(ii) Trapezoidal channel section for larger discharges

The velocity or depth may be limited for designing a trapezoidal ch. section

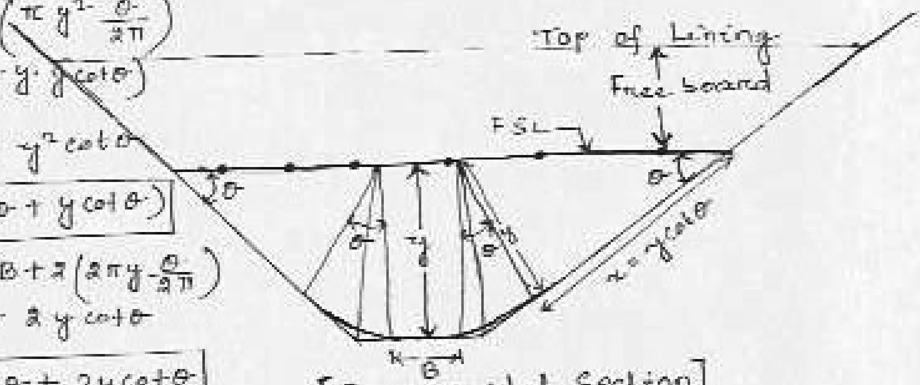
Area = $B \cdot y + 2\left(\pi y^2 \frac{\theta}{2\pi}\right) + 2\left(\frac{1}{2} \cdot y \cdot y\cot\theta\right)$

or $A = By + y^2\theta + y^2\cot\theta$

or $\boxed{A = y(B + y\theta + y\cot\theta)}$

Perimeter (P) = $B + 2\left(2\pi y \frac{\theta}{2\pi}\right) + 2y\cot\theta$

or $\boxed{P = B + 2y\theta + 2y\cot\theta}$



[Trapezoidal Section]

★ Inorder to increase A/P ratios the corners are rounded and attempts are made to use deeper sections by limiting depths etc.

Problem:

Design a concrete lined channel to carry a discharge of 350 cumecs at a slope of 1 in 5000. The side slope of the channel may be taken as 1½ : 1. The value of n for lining is 0.014. Assume limiting velocity in the channel as 2 m/s.

Solution:

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

$$2 = \frac{1}{0.014} R^{2/3} \frac{1}{\sqrt{5000}}$$

or $R^{2/3} = (2 \times 0.014 \times 70.8)$

$R = (1.98)^{3/2} = 2.79\text{m}$ ------ (i)

For trapezoidal channel section (since flow involves a larger discharge)

1.5 / 1 : $\cot\theta = b/p$

$180° = \pi$ radians

$\cot\theta = 1.5$; $\theta = 34.1° = 0.59$ radians

$A = y(B + y\theta + y\cot\theta)$

or $A = y(B + 0.59y + 1.5y) = y(B + 2.09y)$

or $A = y(B + 2.09y)$

$P = (B + 2y\theta + 2y\cot\theta) = (B + 2 \times 0.59y + 2 \times 1.5y)$

or $P = (B + 1.18y + 3y) = B + 4.18y$

or $P = B + 4.18y$.

But $A = \frac{Q}{V} = \frac{350}{2} = 175\text{ m}^2$.

$175 = y(B + 2.09y)$

or $\frac{175}{y} = B + 2.09y$ or $B = \frac{175}{y} - 2.09y$ ------ (ii)

From (i) we get,

$$2.79 = \frac{A}{P} = R = \frac{175}{B + 4.18y}$$

$$2.79 = \frac{175}{B + 4.18y}$$

Substituting the value of B from (ii) we get,

$$2.79 = \frac{175}{\left(\frac{175}{y} - 2.09y\right) + 4.18y}$$

or $\left[\frac{175}{y} - 2.09y\right] + 4.18y = \frac{175}{2.79} = 62.7$

or $175 - 2.09y^2 + 4.18y^2 = 62.7y$

or $2.09y^2 - 62.7y + 175 = 0$; or $y^2 - 30y + 83.7 = 0$

or $y = \frac{30 \pm \sqrt{900 - 334.8}}{2}$

or $y = \frac{30 \pm 23.8}{2} = \frac{30 - 23.8}{2} = 3.2$ mts.

(ignoring unfeasible +ve sign)

Now, $B = \frac{175}{y} - 2.09y$

or $B = \frac{175}{3.2} - 2.09 \times 3.2$

or $B = 54.7 - 6.7 = 48$ m

or $B = 48$ m

Using free-board of 0.75m, we have depth of lined canal
$= (3.2 + 0.75) = 3.95$ m

Bed Width, B = 48 m.
Total Depth, D = 3.95m } Ans.

[Assignments]

1. Describe various types of canal linings & discuss their relative advantages & disadvantages.

2. Write down the cause and control of water-logging.

TYPES OF LININGS.

Hard Surface Linings (or Rigid lining)

(1) Cast insitu Cement Concrete lining
(2) Shotcrete or Plaster Lining
(3) Cement Concrete tile lining or Brick Lining.
(4) Asphaltic Concrete lining.
(5) Boulder Lining.

Earth Type linings.

(1) Compacted Earth lining.
(2) Soil cement lining.

1. CAST INSITU CEMENT CONCRETE LINING.

(1:2:4)

- Cement concrete lining made from M15 cement concrete mix (1:2:4) is considered a good quality type of lining.
- Such lining provide satisfactory service, and are widely used due to their durability, impermeability, hydraulic efficiency and for providing weed free surface.
- Initial cost of C.C. lining is high, yet its long life & min^m maintenance cost usually makes it an economical type of lining over the life span.

e.g.; Use of concrete lining in India,
Bhakra-Nangal Project (About 570 km length of channels); Sarda Canal in U.P. etc. Tungabadhra Project, Amravati Project,

Advantages

- → Longer Life
- → Least permeable
- → Most resistant to erosion
- → Permits fast construction by mechanical means.
- → Low recurring maintenance charges.

Disadvantages

- → Higher initial cost
- → Greater Possibility of temp. cracking.
- → Less flexible & easily affected by adverse subgrade conditions.
- → Skilled supervision & construction necessary.

2. SHOTCRETE LINING (IS: 9012-1978 "recommended practice for shotcreting".)

- Application of cement mortar under pressure through a nozzle on the surface of the channel.
- Consists of a mixture of cement & sand (1:4).
- Larger proportions of cement are required in shotcrete as compared to what is required in cement concrete.
- Also useful for repair works & rehabilitation of old canals.
- Shotcrete linings can be placed on an irregular canal section, thus eliminating the necessity of trimming the section, as is required for concrete canals.
- Generally laid in a thickness of about 3.5 cm.
- Excavation, Compaction, Curing etc. for a shotcrete lining are the same as those required for a cement concrete lining.
- Convenient for lining small sections, for repair old linings, and for placing linings around curves or structures.

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Hard Surface Linings (Rigid Linings)
1 Cast insitu cement concrete &
2 Shotcrete or Plaster lining
3 Cement concrete tile lining & Brick Lining
4 Asphaltic Concrete lining
5 Boulder lining

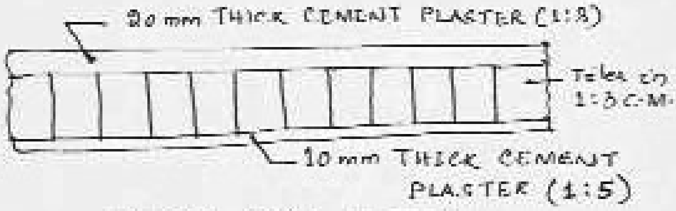
Earth Type linings
1. Compacted Earth lining
2. Soil Cement lining

3. CEMENT CONCRETE TILE LINING (OR) BRICK LINING -

- Brick linings are very popular in India because of certain inherent advantages in their use.

Advantages

1. Concrete tiles or Bricks can be laid by ordinary masons
2. Rigid quality control is not required.
3. No expansion joints are required.
4. Rounded sections can be easily laid without using any formwork.
5. Isolated damaged portions can be repaired easily.
6. Bricks can be plastered to increase the carrying capacity of canal with the same section, and also to help increase the life span of lining.

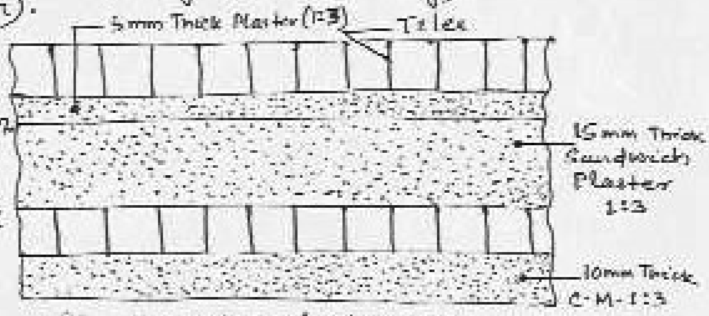


(Single Tile Lining)

Laying:

→ The top layer is generally laid in 1:3 cement mortar over 15 mm thick layer of of plaster (1:3 cement plaster).

Size of tiles generally restricted to 30 mm x 150 mm x 33 m



(Double Tile Lining)

This type of lining is stable even if there is settlement of foundation, since the mortar joint between the bricks or tiles provide for numerous cracks so fine that seepage is insignificant.

IS: 3860 - 1966 "Specifications for precast cement concrete canal linings".
IS: 3872 - 1966 "Code of practice for lining of canal with burnt clay tiles".
IS: 10646 - 1991 "canal linings - cement concrete tiles".

4. BOULDER LINING

- Also called dry stone lining or stone pitching.
- Consists of lining the side slopes of an earthen canal by proper placement and packing of stones, either after laying a filter layer over the soil surface or without any such filter, depending upon the site requirement.
- To reduce the resistance to flow, a 20-25 mm thick cement plaster is provided as a finishing surface.

- One biggest advantage of this type of lining is allowing free flow water from the submerged or saturated sub-grade into the canal. Hence this type of lining doesnot need any drainage arrangement or pressure relief valves etc. which may be required for concrete or brick lining.
- Such a lining may therefore be preferred when watertable is very high in the area, higher than even FSL of the canal.

IS: 4515 : 1976: "code of practice for boulder lining of canals."

5. EARTH LININGS

Different types of earth linings that are used in canals includes:

(i) Stabilized Earth Linings: The sub-grade is stabilized using either clay for granular sub-grade or by adding chemicals that compact the soil.

(ii) Loose earth blankets: fine-grained soils is laid on the sub-grade and evenly spread. This type of lining is prone to erosion & requires a flatter side slopes of canal.

(iii) Compacted earth linings: Graded soil containing about 15 % clay is spread over the sub-grade & compacted.

(iv) Buried Bentonite Membranes: Buried bentonite linings for canals are constructed by spreading soil-bentonite mixtures over the sub-grade & covering it with gravel or compacted earth. (Bentonite is a special type of clay soils found naturally, which swell considerably when wetted).

(v) Soil-Cement Lining: Cement & sandy soil are mixed and then compacted at optimum moisture content or cement & soil is machine mixed with water and then laid.

IS: 7113 - 1973 "code of practice for soil cement lining of canals."