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Study and Design of Cement Concrete Lining of Canal

Shivangi Singh∗, Dr.Rakesh Varma∗∗, Dr.D.S.Ray∗∗∗
∗Research Scholar (Author) ∗∗Professor SRMU.CE (Rtd) UP Irrigation(Co-Author) ∗∗∗ Professor and Hod, BBD ITM (Co-Author)

Abstract
Canals transport water from lakes, rivers, etc., to human use like irrigation and water supply in urban areas.Canal construction is too costly an affair.Seepage loss accounts for nearly 23% to 47% through its bed and sides of the canal.To improve the efficiency water carrying capacity of the canal,different types of lining are provided over the bed and sides of the canals to make the bed and sides impervious which will the life and discharge of the canal. Canal lining obstructs seepage flow through the bed and the sides. Canal linings are constructed with different materials such as compacted earth, cement concrete, plastics, boulders, bricks, etc.
Seepage loss mainly depends on soil characteristics of which sides and beds of canals have been constructed. Many types of canal lining are used based on the characteristics of the soil, permeability of the soil, and funds available. The best-suited lining of the Indian canal is CC lining if sufficient funds are available.
Keywords: Lining, Seepage, Cement Concrete, Rugosity, Longitudinal slope

1. Introduction

Canal Lining is an impermeable layer provided for the bed and sides of the canal to improve the life and discharge Capacity of the canal. Construction canal lining can save 60 to 80% of water lost through seepage in an unlined canal. Canal linings are provided in canals to resist the flow of water through its bed and sides. These can be constructed using different materials such as compacted earth, cement, concrete, plastics, boulders, bricks, etc. The main advantage of canal lining is to protect the water from seepage loss.

1.1 CANAL LINING

Canal Lining is provided in canals to resist water flow through the bed and the sides of the canal. It can be constructed sing different types of materials such as cement, bricks, boulders, plastics, compacted earth, concrete, etc. Canal lining refers to an impermeable layer provided to resist the seepage losses from the beds and sides of the canal. Around 60-80% of the water losses can be prevented by providing canal linings.

Canal lining is an effective technique employed to enhance the effectiveness and durability of irrigation canals. It takes the application of impermeable materials like concrete, asphalt, plastic, or clay to the canal's sides and base.

This addition effectively minimizes water loss through seepage and evaporation. Consequently, canal lining contributes to substantial water conservation that would otherwise be wasted in unlined canals, leading to increased water availability for irrigation and other essential applications.

Canal lining provides a protective layer to the sides and bed of a canal to prevent water seepage and erosion. This lining, often made of concrete, clay, or synthetic materials, not only conserves water but also improves flow efficiency and reduces maintenance costs, ensuring the long-term sustainability of irrigation systems.

Canal lining involves covering the sides and bottom of an irrigation canal with materials like concrete, asphalt, plastic, or clay. This process minimizes water loss caused by seepage and evaporation. By lining canals, water can be efficiently conveyed, reducing waste and increasing the available water supply for irrigation and other purposes.

The bed and sides of a canal need to be protected, and this is where the canal lining comes in. The typical lining thickness ranges from 2.5 to 15 cm and is built from RCC or CC bricks, stones, etc.

Water flowing through the canal system may be lost to seepage before reaching an irrigable region, resulting in insufficient water for the crops. Therefore, it's important to establish an impermeable layer on the canal's bed and des to reduce

1.2 IMPORTANCE OF CANAL LINING

- It is adopted to minimize the seepage losses of the canal water.
- It is also done to prevent the bed and sides of the canal from scouring and silting.
- It is also adopted for increasing the velocity of canal water flow. Thus, the discharge of the canal section is also increased.
- The phenomenon of water logging can also be prevented by lining the canal.
- Canal lining is also done to prevent the growth of weeds and unwanted vegetation along the bed and sides of the canal.
- Lining the canal minimizes the maintenance cost of the canal.

1.3 FACTORS

- Canal lining depends on the following factors.
- Imperviousness
- Hydraulic efficiency
- Durability
- Structural stability
- Economy
- High velocity
- Life
- Weed Growth
- Availability of construction materials
- Availability of labour
- Operation and maintenance charges
- Subgrade
- Resistance to abrasion

1.4 ADVANTAGES OF CANAL LINING

1. Seepage Reduction
2. Prevention of Water Logging
3. Increase in Commanded Area
4. Increase in Channel Capacity
5. Less Maintenance
6. Safety Against Floods

1.5 DISADVANTAGES OF CANAL LINING

Some of its disadvantages are:

- The initial investment is high in canal lining.
- Shifting of the outlet is high because it involves dismantling and relaying the lining.
- The construction period of the lined canal is longer.
- Skilled labor and sophisticated construction equipment are required for canal lining.

2. Cement Concrete Lining

Concrete lining for canals is recommended only where the cost is justified over other types of lining. Salient points regarding concrete lining are discussed as under:

2.1 MATERIALS: Concrete linings are made of cement, aggregates, and water. The lining can be placed by machines or laid manually.

2.2 SUBGRADE PREPARATION: For a plain concrete lining to be free from cracks due to the settlement of the subgrade, the foundation should be firm. Natural earth in cutting is generally acceptable. When laying the lining on the bank, thorough compaction of the earth should be ensured. To avoid the development of back pressure on the lining when the banks get saturated by rains, it may be necessary to provide drainage of banks formed of soils having low permeability. It is, however, not necessary in average or sandy soils.

2.3 THICKNESS OF CONCRETE LINING: The thickness varies from 5 to 15 cm. Smaller channels require 5 cm thickness while large canals need 8 cm on average. The banks are dressed to a self-supporting slope of 1:(V)1.5 (H): 1 (V) to 1.25 (H)

2.4 **SLOPE:** Where the slopes are steeper than this, the thickness of the concrete lining increases steeply rendering it uneconomical. me thickness of the lining depends on the requirements of impermeability and structural strength necessary to avoid cracking with minor movement of the subgrade.

Table 1: Thickness of Concrete Lining

No.	Canal Capacity(cumec)	Thickness with MIS Concrete (cm)		Thickness with MIO Concrete (m)	
		Controlled	Ordinary	Controlled	Ordinary
1.	O to 5	5.0	6.5	7.5	7.5
2.		6.5	6.5	7.5	7.5
3.		8.0	9.0	10.0	10.0
4	50 to 100	9.0	10.0	12.5	12.5

5	100 and above	10.0	10.0	12.5	15.0

2.5 REINFORCEMENT IN CONCRETE LININGS: The purpose of providing steel reinforcement in the lining is to reduce the width of temperature or shrinkage cracks, thus reducing seepage, and to protect the cracked slabs from faulting in case of unstable subgrade soils. Steel being costly is generally omitted except where the structural safety of lining particularly requires it. However, steel reinforcement interferes with the. working of mechanical equipment used for laying the lining. The amount of. reinforcement varies from 0.1 to 0.4 % of the concrete area in the longitudinal direction, and 0.1 to 0.2% of the concrete area in the transverse direction.

2.6 JOINTS: Special contraction joints are provided in concrete linings on important works. The spacing is kept at 50 times the lining thickness in case of unreinforced lining.

2.7 LAYING OF CONCRETE LINING: Concrete is laid without formwork on slopes flatter than. 1: 1. me concrete mix should be of a consistency such as to be well compacted, and yet stay on the slopes without formwork on such slopes. Concrete with low workability will result in honeycombing, while high workability will cause the concrete to flow down the slope and result in a wavy surface.

The subgrade should be saturated to a depth of 30 cm in sandy soils and 15 cm in other types of soils before laying the concrete lining so that moisture from the mix is not lost due to any absorption by the subgrade. Painting the subgrade with a film of crude oil or covering the subgrade with a sheet of oil paper prevents the possibility of mudding and uneven subgrade that may occur on saturation.

Various types of buried membrane lining are available. It is easy to lay; and can be laid in cold and hot weather also. It is quite flexible adjusting readily to the settlements in subgrade. Some types like polyethylene film type can get ruptured by sharp stones, andare liable to damage by weed growth.

We cannot permit a high flow velocity due to earth covering, and its useful life is limited.Channels lined with hard surfaced materials, such as concrete, brick tiles, asphaltic concrete, etc., have the advantage that higher velocities of flow may be allowed and a section hydraulically more efficiently than unlined channels or canals lined with soft materials can be designed, Higher hydraulic efficiency is obtained by increasing the hydraulic mean depth which is the ratio of flow area to wetted perimeter. This is possible by avoiding corners and adopting appropriately deeper sections (for the same flow area) that are practicable in unlined channels. For small channels, a triangular section with a circular bottom, and for larger canals a trapezoidal section with rounded comers may be adopted.

3. Design Procedures

Lined canals are usually designed by using Manning's equation. Table gives the values of Manning's n for different materials.

Table 2 Values of Rugosity Co-efficient.

	Surface	Value of n
1	Concrete surface: (a) Formed, no finish (b) Trowel finish (c) Float finish (d) Float finish with some gravel on the bottom	0.013- 0.017 0.012 -0.014 0.013 -0.015 0.015 -0.017 0.016 -0.019 0.018 -0.022

2	The concrete bottom float is finished but the sides with (a) Dressed stone in mortar (b) Random stone in mortar (c) Cement rubble masonry (d) CenEnt rubble masonry plastered (e) Dry rubble or rip rap	0.015 0.017 0.017- 0.020 0.020-0025 0.016 -0.020 0.020 -0.030
3	Gravel bottom but sides with (a) Formed concrete (b) Random stone in mortar (c) Dry rubble or rip rap	0.020 0.017 0.023 0.023 -0.033
4	Brick	0.014 -0.017
5	Asphalt	0.016

4. Design Parameters

- The design considerations naturally vary according to the type of soil.
- Velocity of flow in the canal should be critical.
- The design of canals which are known as 'Kennedy's theory' and 'Lacey's theory' are based on the characteristics of sediment load (i.e. silt) in canal water.

4.1 IMPORTANT TERMS RELATED TO CANAL DESIGN

- Alluvial soil
- Silt factor
- Co-efficient of rugosity
- Mean velocity
- Critical velocity
- Critical velocity ratio (c.v.r), m
- Regime channel
- Hydraulic mean depth
- Full supply discharge Economical section

4.1.1 ALLUVIAL SOIL

The soil which is formed by the continuous deposition of silt is known as alluvial soil. The river carries a heavy charge of silt in the rainy season. When the river overflows its banks during the flood, the silt particles get deposited in the adjoining areas. This deposition of silt continues year after year. This type of soil is found in the deltaic region of a river. This soil is permeable soft and very fertile. The river passing through this type of soil has a tendency to change its course.

4.1.2 SILT FACTOR

During the investigations works in various canals in alluvial soil, Gerald Lacey established the effect of silt on the determination of discharge and the canal section. So, Lacey introduced a factor which is known as the 'silt factor'. It depends on the mean particle size of silt. It is denoted by 'f'. The silt factor is determined by the expression,

f = 1.76mn

where d_{mm} = mean particle size of silt in mm

Particle	**Particle size (mm)**	**Silt factor (f)**
Very fine silt	0.05	0.40
Fine Silt	0.12	0.60
Medium Silt	0.23	0.85
Coarse slit	0.32	1.00

4.1.3 COEFFICIENT OF RUGOSITY (N)

The roughness of the canal bed affects the velocity of flow. The roughness is caused due to the ripples formed on the bed of the canal. So, a coefficient was introduced by R.G Kennedy for calculating the mean velocity of flow. This coefficient is known as the coefficient of rugosity and it is denoted by 'n'. The value of 'n' depends on the type of bed materials of the canal.

Materials	Value of n
Earth	0.0225
Masonry	0.02

Concrete	0.013 to 0.018

4.1.4 MEAN VELOCITY

It is found by observations that the velocity at a depth of 0.6D represents the mean velocity (V), where 'D' is the depth of water in the canal or river.

(a) Mean Velocity by Chezy's expression:

V = CRS

(a) Mean Velocity by Manning's expression**:**

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

4.1.5 CRITICAL VELOCITY

When the velocity of flow is such that there is no silting or scouring action in the canal bed, then that velocity is known as critical velocity. It is denoted by 'Vo'. The value of V. was given by Kennedy according to the following expression,

$Vo = 0.546\ D^{0.64}$ where D =Depth of water

4.1.6 CRITICAL VELOCITY RATIO (C.V.R)

The ratio of mean velocity 'V' to the critical velocity 'V' is known as the critical velocity ratio (CVR). It is denoted by m. CVR (m) = VN_o.

When m=1, there will be no silting or scouring.

When m> 1, scouring will occur

When m< 1, silting will occur

So, by finding the value of m, the condition of the canal can be predicted whether it will have silting or scouring

4.1.7 REGIME CHANNEL

When the character of the bed and bank materialsof the channel isthe same as that of the transported materials and when the silt charge and silt grade are constant, then the channel is said to be in its regime and the channel is called regime channel. This ideal condition is not practically possible.

4.1.8 HYDRAULIC MEAN DEPTH/RATIO

The ratio of the cross-sectional area of flow to the wetted perimeter of the channel is known as hydraulic mean depth or radius. It is generally denoted by R.

R = A/P

Where,

A = Cross-sectional area

P = Wetted perimeter

4.1.9 FULL SUPPLY DISCHARGE

The maximum capacity of the canal for which it is designed is known as full supply discharge. The waterlevel of the canal corresponding to the full supply discharge is known as the full supply level (F.S.L).

4.1.10 ECONOMICAL SECTION

If a canal section is such that the earth obtained from cutting (i.e. excavation) can be fully utilized in forming the banks, then that section is known as an economical section. Again, the discharge will be maximum with minimum cross-section area. Here, no extra earth is required from the borrow pit and no earth is in excess to form the spoil bank. Thiscondition can only arise in the case of partial cutting and partial banking. Sometimes, this condition is designated as a balancing of cutting and banking. Here, the depth of cutting is called balancing depth.

5. Design Of Lined Canals:

Design Parameters:

(i) Area(A)=BD+2$\pi D^2(\theta/2\pi)$ +2$D^2(Cot\theta/2\ )$

= BD+$D^2(\theta + Cot\theta)$

(ii) Wetted Perimeter (P)= B+2π D(θ/π) +2D$(Cot\theta\ )$

(iii) HydraulicRadius (R) = A/P

(iv) Longitudinal Slope, S

(v) Velocity,v = Q/A

(vi) Velocity,v = 1/n * $R^{2/3}$* $S^{1/2}$

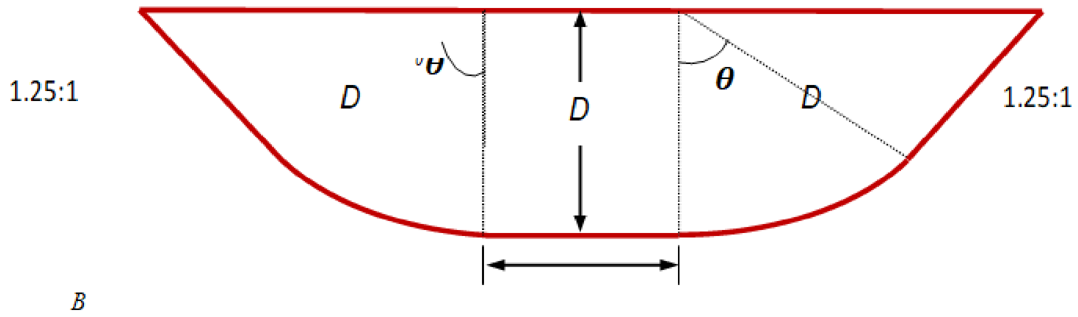
(vii) Discharge,Q = 1/n*A*$R^{2/3}$* $S^{1/2}$

If side slope 1.25:1

(i)Sectional Area(A)=BD+1.925D^2

(ii) Wetted Perimeter (P)= B+3.85 D

(iii) HydraulicRadius (R) = A/P=(BD+1.925$D^{2)}$/(B+3.85 D)



Design parameters for trapezoidal section

Indira Canal Chainage 171.00 to 172.00

As per Is No. 945: 1994 Guidelines for the lining of camels in expansive

1. value of rugosity Co-efficient - (n) trowel float finish (Table-1) - 0.015 – 0.018
2. Table 2. Recommended side slopes (clause 8.1.1) -C.C. 1.25: 1
3. Free board More than 10 cumec- 0.75m.
4. Bank Top width 30.0 and above - Inspection bank/wider bank – 60 m+dowel.
5. 15 3873: 1993 - Laying cement- Concrete/ Stare slab Lining on the canal - code of practices thickness of in-situ concrete lining.

Capacity 50-200 Cumec – Depth twain -2.5-4.50

Thickness of lining- 75-100 mm

6. Limiting velocity in different types of Lining

(a) Stone pitched lining - 1.5 rn/scc

(b) Burnt clay tiles or brick lining -1.8m/sec

(c) Concrete Lining - 2.7 ml sec

DATA

(i)Discharge = 195 cumec

(ii) Rugosity (n) for concrete Living -0.015

(iii) Side slope for concrete living = 1.25:1

(IV) Lining velocity of concrete Lining = 1.95 m/sec

(V) Bed width(B)- 50m

1. Cross Section Area (A) = $\frac{Q}{v} = \frac{195}{1.95} = 100\ sqm$

2. A = BD +1.925 BD^2

⇒ 100 = 501 + 1.925 x D^2

⇒ 100 = 50D+ 1·925-D^2

Or 1.925 D2+50D -100

$$Quadratic\ equation, D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-50 \pm \sqrt{2500 - 4.1.925.(-)100}}{2.1.925}$$

$$= \frac{-50 \pm \sqrt{2500+770}}{2.1.925}$$

$$\frac{-50 \pm \sqrt{2500+770}}{2.1.925}$$

$$= -50 + \frac{57.18}{2x1.925} = .\frac{7.18}{2x1.925} = 1.87\ m$$

D= 1.87m

3. Perimeter (P) = B + 3.85 * D

= 50 + 3.85 x 1.87

= 50 + 7.18

= 57.18m

4. Hydraulic Radius, R = A/P

$$= \frac{100}{57.18} = 1.75\ m$$

5. Discharge== $\frac{1}{n}AR^{2/3}S^{1/2}$

6. $Q = \frac{1}{n}AR^{2/3}S^{1/2}$

Or 195 $= \frac{1}{0.015} * \ 100 * 1.75^{2/3}S^{1/2}$

Or $S^{1/2} = 195\,x\frac{0.015}{100} * 1.75^{\frac{2}{3}} = 195\,x\frac{0.015}{100x} *$ 1.452

Or $S^{1/2} = \frac{2.925}{145.20} = 0.02014$

$= 0.0004$

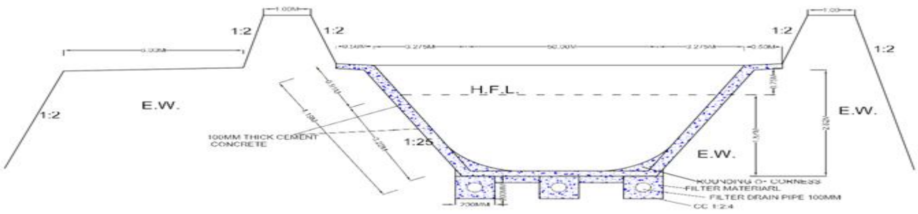
$= 1 in\ 2500$

S= 1 in 2500

6. Free Board

More than 10 cumec – 0.75m

7. Total depth top to bed=1.87+0.75 =2.62 m



A-TYPICAL CROSS -SECTION OF CANAL
(INDIRA CANAL CHAINAGE 171.000 TO 172.000)

6. Conclusion

A typical cross-section of cement concrete lining of the Indira Canal of chainage 171.00 to 172.00, laying in Lucknow Distt, has been designed in Chapter 5 and A typical drawing has been drawn in Chapter- 5. Design and drawing have been done with different IS: Code of water resources and Irrigation.

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