UNIT 9 LINED CANALS

Structure

9.1 Introduction
  Objectives

9.2 Purpose of Lining

9.3 Selection of Lining Material

9.4 Types of Lining
  9.4.1 Concrete Lining
  9.4.2 Precast Concrete Lining
  9.4.3 Lime Concrete Lining
  9.4.4 Shotcrete or Gunite Lining
  9.4.5 Brick Tile Lining
  9.4.6 Asphalt Lining
  9.4.7 Stone Blocks, Undressed Stones or Concrete Blocks in Lining
  9.4.8 Earth Materials in Lining
  9.4.9 Prefabricated Light Weight Membrane Lining
  9.4.10 Bentonite Soil and Clay Membrane Lining
  9.4.11 PVC Film Lining
  9.4.12 Porous Lining

9.5 Lined Sections

9.6 Design Procedures

9.7 Drainage Behind Lining

9.8 Cost of Lining

9.9 Summary

9.10 Key Words

9.11 Answers to SAQs

9.1 INTRODUCTION

Canals are lined to reduce seepage losses, and to the chances of waterlogging in a given area. Various types of lining options are available, and the selection of a particular type is related to cost effectiveness and ready availability. Lined channels are non-erodible, and hence their design theories are different from those of unlined canals.

Objectives

By the end of this unit you should be able to understand

- the purpose of lining a canal,
- how you will select materials for lining,
- various types of lined sections,
- the method of designing lined canals,
- the method of draining behind the lining,
- cost of lining, and
- the economics of canal lining.

9.2 PURPOSE OF LINING

Lining an irrigation canal serves the following purposes :

(a) It helps to reduce seepage losses which saves water that can be utilised to irrigate additional areas.

(b) It reduces maintenance costs and probability of canal breaching as a result of increased stability that is achieved by the canal section.

(c) It reduces percolation to the ground water reservoir and thus prevents waterlogging. However, the water thus saved should not be used to carry out more intensive irrigation in the same area as this will promote waterlogging itself.

(d) It helps, where the ground slope is mild, in improving the command due to flatter slopes. In situations where the canal is also used for power generation, this is an additional benefit since the lined canal can be given a flatter slope resulting in a higher head that would be available for the power generation.

(e) It prevents the growth of weeds.

9.3 SELECTION OF LINING MATERIAL

The material selected for lining an irrigation channel should have the following characteristics with a view to its being adequately effective :

(a) **Water tightness :** It is the most important characteristic of a lining. It imparts a measure of impermeability and helps save seepage losses.

(b) **Hydraulic efficiency :** It represents the discharging capacity of the channel section, and is influenced by the coefficient of rugosity of the material.

(c) **Initial cost and recurring maintenance costs :** The material selected for lining should be moderate in first cost and cheap to maintain.

(d) **Strength and durability :** The lining should be strong and durable, but at the same time have a reasonable degree of flexibility to adapt itself to slight unevenness of the subgrade on which it is laid. A durable lining can withstand the effects of weathering and chemical attack. Weathering is wearing of the surface caused by the alternate cycles of freezing and thawing in cold countries and by alternate expansion and contraction due to changes in temperature, and repeated cycles of wetting and drying occurring in all climates. The durability is measured by the coefficient of expansion and water absorption characteristic of the lining. Any hardened surface can withstand wear but concrete linings deteriorate when they are in contact with soils containing sodium sulphate and certain other salts.

(e) Resistance to attack by burrowing animals and weed growth.

9.4 TYPES OF LINING

Channels are lined by any of the following materials:

(1) Concrete (in-situ construction)

(2) Precast concrete (tiles)

(3) Lime concrete

(4) Shotcrete or gunite

(5) Brick tiles

(6) Asphalt –

  (a) Buried asphalt membrance

  (b) Asphaltic concrete

(7) Stone blocks, concrete blocks or undressed stones.

(8) Earth materials –

  (a) Compacted earth

  (b) Soil cement

(9) Prefabricated light-weight membranes

(10) Bentonite - soil and clay membranes

(11) PVC films

SAQ 1

What are the various materials used for lining a channel? Collect some field examples and discuss.

9.4.1 Concrete Lining

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

(a) **Materials :** Concrete linings are made of cement, aggregates and water. The lining can be placed by machines or laid manually.

(b) **Subgrade preparation :** For a plain concrete lining to be free from cracks due to 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.

(c) **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 an average. The banks are dressed to a self supporting slope of 1.5 (H) : 1 (V) to 1.25 (H) : 1 (V). Where the slopes are steeper than this, the thickness of the concrete lining increases steeply rendering it uneconomical. The thickness of lining depends on the requirements of impermeability and structural strength necessary to avoid cracking with minor movement of the subgrade.

Table 9.1 gives the minimum thickness of concrete lining for different concrete mixes.

Table 9.1 : Thickness of Concrete Lining

Sl. No.	Canal Capacity (cumec)	Thickness with M15 Concrete (cm)		Thickness with M10 Concrete (m)	
		Controlled	Ordinary	Controlled	Ordinary
1.	0 to 5	5.0	6.5	7.5	7.5
2.	5 to 15	6.5	6.5	7.5	7.5
3.	15 to 50	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

(d) **Reinforcement in concrete linings :** The purpose of providing steel reinforcement in 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.

(e) **Joints :** Special contraction joints are provided in concrete linings on important works (Figure 9.1). The spacing is kept as 50 times the lining thickness in case of unreinforced lining. Figure 9.2 shows the details of a typical construction joint.

(f) **Laying of concrete lining :** Concrete is laid without formwork on slopes flatter than 1 : 1. The 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 a high workability will cause the concrete to flow down the slope and result in a wavy surface.

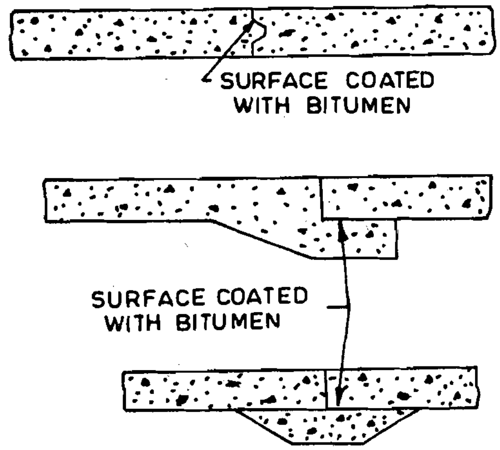

Figure 9.1 : Joints in Concrete Lining

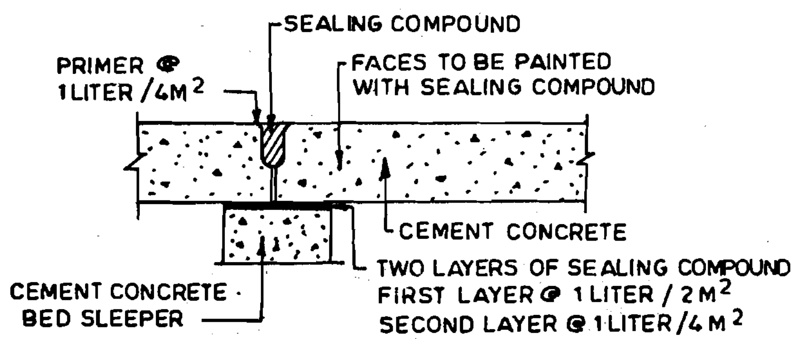

Figure 9.2 : Details of Construction Joints

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 by 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.

Figure 9.3 shows a typical two layer lining of monolithic concrete.

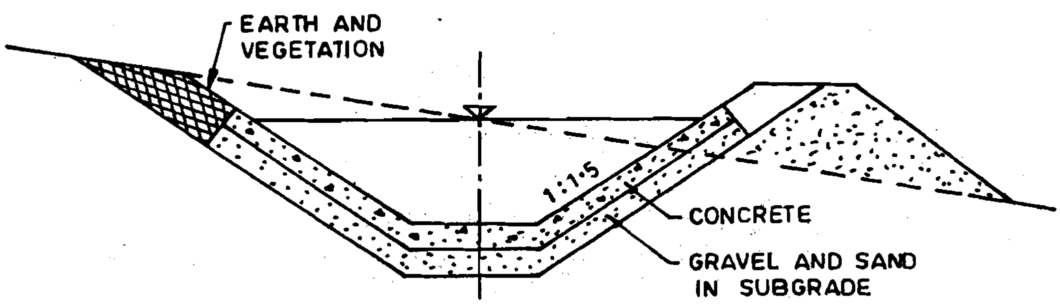

Figure 9.3 : Two-layer Lining of Monolithic Concrete

This lining is quite impermeable, strong and durable. Its coefficient of rugosity is low, permitting high velocity of flow; thus, silting and evaporation losses get reduced. Mechanical equipment allows quick construction; and its maintenance cost is low. It discourage weed growth. However, its initial cost is quite high, and also it may develop cracks due to temperature fluctuations. Its repair process is difficult and costly. Due to its relatively small thickness its resistance to hydrostatic pressure (after rapid drawdown in the canal) is limited; it is also susceptible to adverse subgrade conditions. Very high velocities may erode its fine ingradients, thus increasing its roughness.

9.4.2 Precast Concrete Lining

Precast concrete slabs laid properly on carefully prepared subgrades, and with joints effectively sealed, provide a lining. These slabs are 5 - 8 cm thick with suitable width and length to suit channel dimensions and they result in a convenient weight to handle. This type of lining is most convenient to repair as it can be placed rapidly without having to shut down the canal for long periods. Figure 9.4 shows the details of a precast slab while Figure 9.5 shows the details of precast concrete lining.

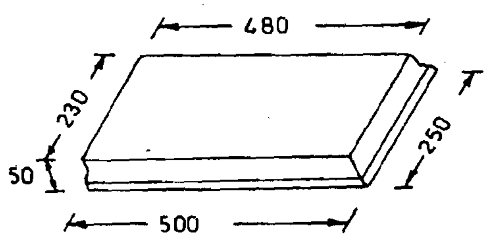

Figure 9.4 : Details of Pre-cast Slab

Being prepared under controlled conditions, the quality of its concrete is good. It is easy to lay, involving less site operations; and it is cheaper compared to in-situ concrete lining. Slabs being of small size, there are less shrinkage cracks; also repair of a damaged unit is easier; and, water pressure from ground water gets released through numerous joints that are there. However, seepage losses are obviously more. Transportation of precast slabs may contribute to breakage.

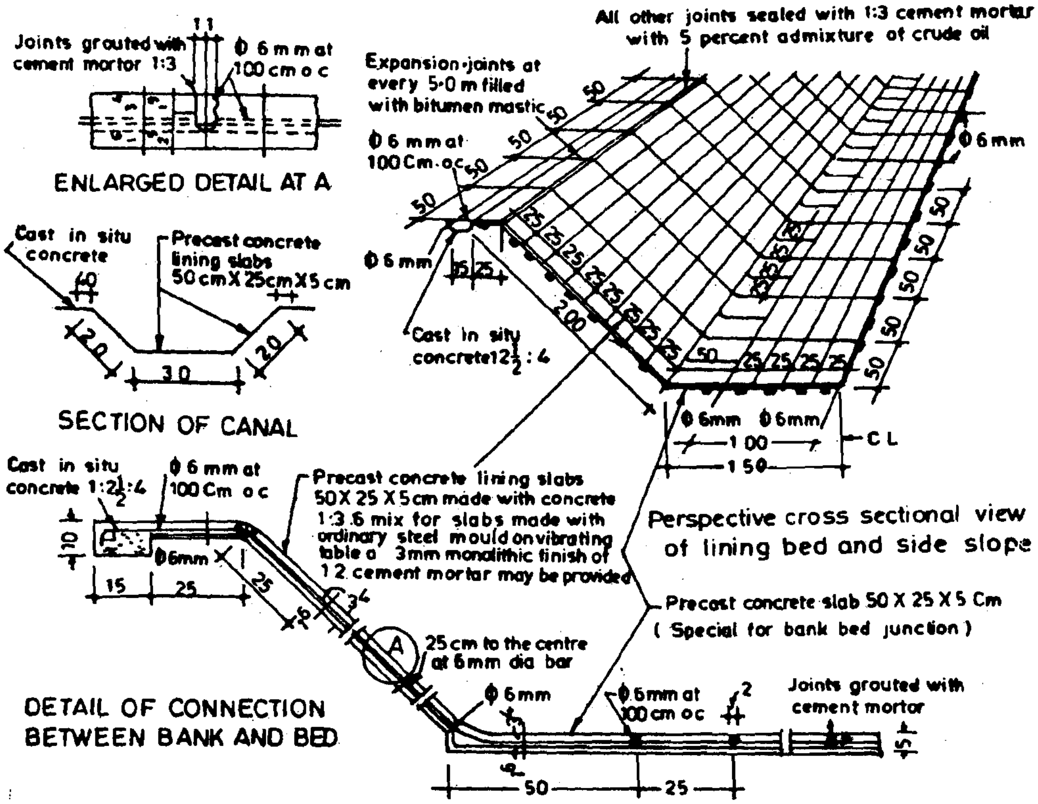

Figure 9.5 : Details of Precast Concrete Lining

9.4.3 Lime Concrete Lining

Such lining is limited to canals having flow upto 200 cumec and in which the velocity is less than 2 m /s. The materials required for this type of lining are lime, sand, coarse aggregate and water. The mix proportions are 1 : 1.5 : 3 of lime : sand : stone (or brick ballast as aggregate). The thickness may vary from 10 - 15 cm for discharges upto 200 cumec.

Lime concrete lining is not as impervious as cement concrete lining. It is not commonly used in practice. It may be stressed that hydraulic lime should not be used in combination with cement as it cause a decrease in the compressive strength of concrete.

9.4.4 Shotcrete or Gunite Lining

Shotcrete or gunite is a mixture of cement, fine and coarse aggregates and water, applied in the form of a spray onto the surface with a special equipment using air under pressure. Water is mixed at the spraying nozzle or in the equipment itself. Shotcrete includes larger sizes of coarse aggregates while gunite has smaller sizes of the coarse fraction. It requires no formwork for laying. The usual thickness of shotcrete layer is 3.5 cm. The service life of shotcrete lining depends on lining thickness, subgrade conditions, operating characteristics and temperature conditions. Shotcrete lining is expensive as compared to concrete lining of equal thickness.

9.4.5 Brick Tile Lining

Brick tile lining consists of one or two layers of brick masonry or tiles laid in mortar. Alternatively, a layer of brickwork is followed by a layer of tiles. The top layer of tiles is usually laid in 1 : 3 cement : sand mortar over 12 mm thick layer of plaster of the same 1 : 3 cement : sand mortar. It may be mentioned that size of tiles is generally kept 30 cm × 15 cm× 5 cm for ease of handling (Figure 9.6). The double tile lining is provided on the banks while a single tile lining is laid on the bed.

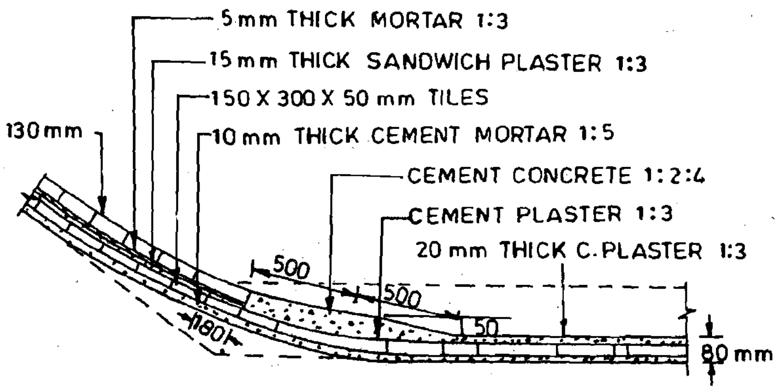

Figure 9.6 : Double Tile Lining on Banks, and Single Tile Lining on Bed

Brick tile lining gives good hydraulic properties. Being flexible, any settlement of the subgrade will cause numerous fine cracks but seepage loss would be insignificant.

It is more pervious than cement concrete lining; and its maintenance cost is higher. Its resistance to abrasion is relatively lower. Laying bricks is a slow process.

For lining work best quality bricks only should be used. The bricks should be well soaked in water before laying. The first layer of brick tiles should be laid on well moistened subgrade. The second layer should be placed at least two days after the plaster has been applied on the first layer.

Brick tile lining for canals has the following advantages :

(a) Brick lining can be laid by ordinary masons not requiring special skills.

(b) The thickness remains constant in case the subgrade is not perfectly plane.

(c) Rigid control on works is not essential, because bricklaying does not require too much skill.

(d) It eliminates the need for expansion joints as shrinkage is practically avoided and the coefficient of expansion is low.

(e) It involves less transport because brick kilns can be established along the canal at frequent intervals.

(f) It is easily repaired in case of damage.

(g) It is easily laid on rounded corners without the need for any formwork.

9.4.6 Asphalt Lining

There are two type of asphaltic canal lining which have been developed and successfully adopted :

(a) Buried asphalt membrane, and

(b) Asphaltic concrete lining.

Buried Asphalt Membrane

The buried asphalt membrane is formed of a thin, 6 mm layer of asphalt sprayed in place at a high temperature of 200°C and covered with a 30 cm layer of earth to protect the membrane. This type of lining is economical where asphalt is available. Being flexible, it conforms to the subgrade profile. But, it does not decrease the rugosity of the channel and prevents weed growth only for a short period. Spraying hot asphalt requires special equipment and trained workmen. A prefabricated asphalt membrane consisting of either a heavy craft paper sprayed with a 5 mm thick layer of asphalt, or a thin sheet of fibreglass sprayed with 3mm thick layer of asphalt is being developed. Such membrane is delivered to the site in rolls where it is laid directly on the subgrade and covered with earth for protection (Figure 9.7). It does not require special equipment or skilled personnel for installing the buried asphalt membrane linings.

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; and is liable to damage by weed growth.

We cannot permit a high flow velocity due to earth covering; and its useful life is limited.

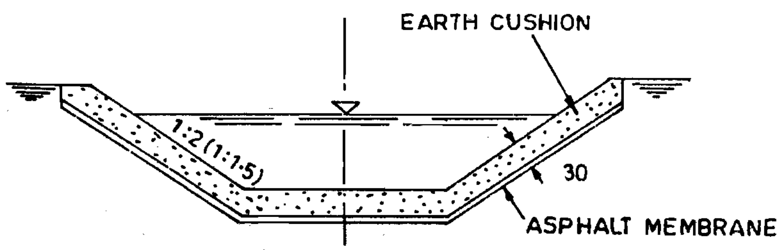

Figure 9.7 : Cross-Section of Canal Sealed by an Asphalt Membrane

Asphaltic Concrete Lining

Asphaltic concrete is a mixture of cement, asphalt and selected aggregates that are mixed while hot. The mix is placed by hand or by equipment similar to that used for cement concrete. It may be used in place of cement concrete and provides a hard surfaced lining. However, it has the disadvantage that weed growth cannot be fully checked and it gives a high coefficient of rugosity without special surface finish.

Asphaltic concrete lining is relatively more flexible, and thus, withstands better any settlement in the subgrade. It can be used for repairing cement concrete lining by laying a resurfacing layer of asphaltic concrete. However, the lining may slide down during hot wheather. It permits certain type of weed to grow causing puncturing of its surface.

9.4.7 Stone Blocks, Undressed Stones (i.e., Boulder Lining) or Concrete Blocks in Lining

Dressed stone blocks are too expensive for lining canals except in short reaches where a very hard surface is required or for aesthetic reasons. Undressed round stones or boulders set in mortar may be provided in regions where boulders are easily available and head loss is not important. Such linings will have a high coefficient of rugosity, but are effective in reducing seepage losses. Boulders split in the middle and using such split boulders with the flat face on the water side will reduce the roughness and thus improve hydraulic efficiency at a relatively small cost. In the hilly regions where boulders are available in abundance and head loss is not of much concern, such linings may be adopted unless the canal is intended for power generation.

Stone blocks have a better wearing resistance than bricks and are suited for steep sided channels, etc., especially in hilly areas.

The size of stones and thickness of lining are given in Table 9.2.

Table 9.2 : Dimension of Stones and Thickness of Lining

No.	Canal discharge (cumec)	Thickness of lining (mm)	Average dimension along longest axis (mm)	Least dimension at any section (mm)
1.	0 to < 50	150	150	75
2.	50 to < 100	225	225	110
3.	100 and above	300	300	150

Precast concrete blocks, for purposes of lining, may be manufactured under carefully controlled conditions at factories located at a few places. The laying of the concrete blocks at site is done by ordinary masons without special control. The construction joints in the lining are avoided and subsequent repairs are easy.

9.4.8 Earth Materials in Lining

Earth materials can also be used for lining canals. These include compacted earth and soil cement mixtures. These types are described below.

Compacted Earth Lining

This is possible in canal reaches where suitable soils are available in the vicinity of the canal alignment. Soil is screened to get the desired characteristics; and it is laid on the subgrade and compacted at optimum moisture content to provide an impermeable and protective lining to resist erosive forces.

Loosely Placed Earth Lining

Suitable clayey soil is spread over the bed and sides of the canal in layers upto a thickness of 30 cm. Seepage losses get reduced, but the treatment may not resist erosion and scour.

Stabilised Soil Lining

Soil stabilised and made impervious by the admixture of specially processed resins and chemicals (such as, sodium silicate, sodium chloride, commercial resins, cement, line, asphalt and petrochemicals) provides a good lining. However, because of use of chemicals the lining becomes quite costly and, may be used under special circumstances.

Soil Cement Lining

Certain soils mixed with 2-5 % portland cement have been found to stabilize the earth making it adaptable for lining of canals. For this, soil containing a high percentage of fine particles (less than 200 microns) is thoroughly mixed with cement and water at site and laid on the prepared surface and well compacted to form an impervious lining.

9.4.9 Prefabricated Light Weight Membrane Lining

Matted fibres of asbestos, jute or other organic materials saturated and coated with bitumen can be laid on a smooth subgrade and covered with a layer of fine soil and gravel. Such membranes are termed prefabricated light weight membranes. Sometimes, the membrane is made of heavy craft paper sprayed with asphalt. The protective layer of earth gives a long life to the lining. It is easy to lay and is quite flexible. High velocities cannot be permitted.

9.4.10 Bentonite Soil and Clay Membrane Lining

In this type of lining granulated bentonite soil and clay membranes are formed as a blanket to check seepage by laying 40 mm thick layer of the membrane over the prepared subgrade. Sometimes bentonite slurry is applied over the subgrade and it penetrates into the subgrade.

9.4.11 PVC Film Lining

The use of impervious membranes has become widespread with the development of the manufacture of plastic materials.

The basic principle of the use of impervious membranes for canal lining is the deposition of the resilient, thin and impervious membrane on the bottom and bank slopes of the canal. The thin PVC impervious membrane is liable to mechanical damage and must therefore be covered with a layer of earth and effectively protected from damage caused by roots (Figure 9.8). A combination lining is also sometimes adopted as shown in Figure 9.9.

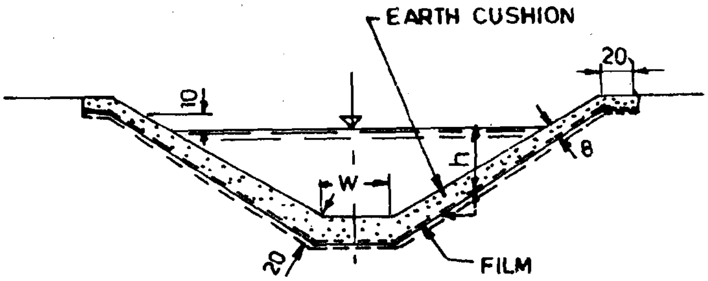

Figure 9.8 : Canal Lining with PVC Film

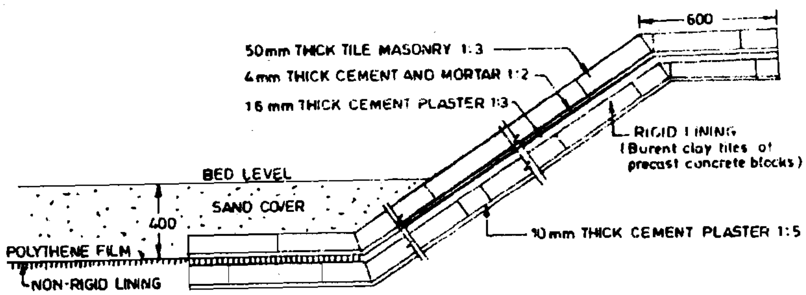

Figure 9.9 : Combination Lining

The deposition of such a lining must be extremely accurate, but its laying is time saving. Such membranes cannot be repaired. In case the membrane is damaged, it has to be replaced. The life span of the membrane will usually be long enough for the canal to be self sealed by colmatage.

9.4.12 Porous Lining

First of all the bed and sides are divided into compartments (not exceeding 15 m in any direction) by laying ribs of stone masonry or cement concrete. Inverted filter of about 15 cm thickness is spread in these compartments. Next, stones are hand packed over the filter. Brick pitching can replace the stone.

Porous lining is commonly provided in the head reaches of the main canal where ground water table may be higher than the bed level of the canal. This ground water passes, through the pores in the lining, into the canal, which in turn causes external hydrostatic pressure on the lining to decrease.

SAQ 2

Describe various types of canal lining with their respective advantages and disadvantages.

How is each type laid? Give sketches of various canal sections with these respective linings on.

9.5 LINED SECTIONS

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 efficient 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 same flow area) that are practicable in unlined channels. For small channels a triangular section with a circular bottom (Figure 9.10) and for larger canals a trapezoidal section with rounded corners (Figure 9.11) may be adopted.

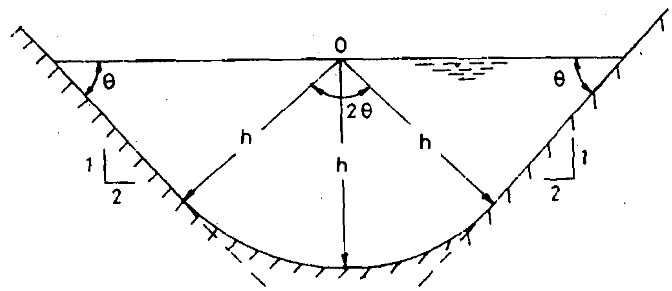

Figure 9.10 : Lined Channel Section for $Q < 55\ m^3/s$

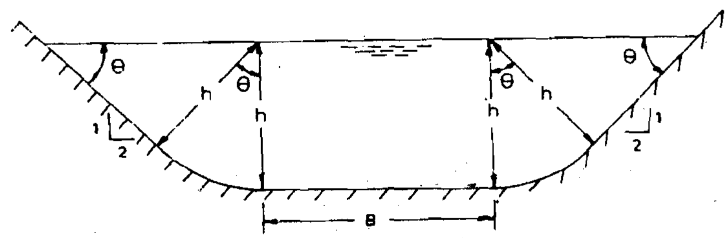

Figure 9.11 : Lined Channel Section for $Q > 55\ m^3/s$

9.6 DESIGN PROCEDURES

Lined channels are usually designed by using Manning's equation. Table 9.3 gives the values of Manning's *n* for different materials.

Table 9.3 : Values of Rugosity Coefficient

No.	Surface	Value of *n*
1.	Concrete surface :	
	(a) Formed, no finish	0.013 - 0.017
	(b) Trowel finish	0.012 - 0.014
	(c) Float finish	0.013 - 0.015
	(d) Float finish with some gravel on bottom	0.015 - 0.017
	(e) Gunite, good section	0.016 - 0.019
	(f) Gunite, wavy section	0.018 - 0.022
2.	Concrete bottom float finished but sides with	
	(a) Dressed stone in mortar	0.015 - 0.017
	(b) Random stone in mortar	0.017 - 0.020
	(c) Cement rubble masonry	0.020 - 0.025
	(d) Cement rubble masonry plastered	0.016 - 0.020
	(e) Dry rubble or rip rap	0.020 - 0.030
3.	Gravel bottom but sides with	
	(a) Formed concrete	0.020
	(b) Random stone in mortar	0.017 - 0.023
	(c) Dry rubble or rip rap	0.023 - 0.033
4.	Brick	0.014 - 0.017
5.	Asphalt	
	(a) Smooth	0.013
	(b) Rough	0.016

A few examples of designing lined channels are presented below.

Example 9.1

Design a concrete lined (trowel finished) canal section for the following given data :

Discharge = 30 cumec

Bed slope = 1 in 6000

Side slopes of the channel = 1.25 : 1 (H : V)

Manning's n = 0.012.

Solution

Assume a triangular lined section as shown in Figure 9.10. Let the central depth and the radius of the central portion be D.

Area $= \pi D^2 (\theta / \pi) + 2\ D^2 (cot\ \theta) / 2$

$= D^2\ (\theta + \cot \theta)$ ... (9.1)

Wetted perimeter $= 2 \pi D (\theta / \pi) + 2 D \cot \theta$

$= 2 D\ (\theta + \cot \theta)$ ... (9.2)

Hydraulic radius $= R =$ Area / Wetted perimeter

$$= \frac{D^2 (\theta + \cot \theta)}{2 D (\theta + \cot \theta)} = D/2 \qquad \text{... (9.3)}$$

where, θ is in the angle made by the sides with top water surface, and is measured in radians.

Now, $V = (1/n)\ R^{2/3}\ S^{1/2}$

$$= \frac{R^{2/3} \cdot (1/6000)^{1/2}}{0.012}$$

$= 1.076 R^{2/3}$

Also, $V = Q / A$

or, $1.076 R^{2/3} = \dfrac{30}{D^2 (0.675 + 1.25)}$

[Note : $\cot \theta = 1.25$ and, $\theta = 0.675$ radians]

As $R = D/2$, we have :

$1.076 (D/2)^{2/3} \times D^2\ (1.925) = 30$

which on solving gives, $D = 3.24$ m. This parameter determines the dimensions of the section.

Example 9.2

Design a concrete lined channel having a trapezoidal section for the following data :

Discharge = 300 cumec

Bed slope = 1 in 9000

Side slopes of channel = 1.25 : 1 (H : V)

Depth of channel is restricted to 4 m.

Adopt Manning's n = 0.012

Solution

Referring to Figure 9.11, let the width of the channel be B and the depth of the central portion be D.

Area $= BD + 2 \pi D^2 (\theta/2 \pi) + 2 \cdot D^2 (\cot \theta) / 2$

$= BD + D^2 (\theta + \cot \theta)$ ... (9.4)

Wetted perimeter $= B + 2 \pi D (\theta/\pi) + 2 D \cot \theta$

$= B + 2 D (\theta + \cot \theta)$ ... (9.5)

In this case, $D = 4$ m, $\cot\theta = 1.25$, and $\theta = 0.675$ radians.

From Manning's equation, we have :

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

$$Q = 300 \text{ cumec}$$

$$A = 4B + 16 \times 0.675 + 16 \times 1.25$$

$$= (4B + 30.8) \text{ m}^2$$

$$P = B + 2 \times 4 \times 0.675 + 2 \times 4 \times 1.25$$

$$= (B + 15.4) \text{ m.}$$

$$\text{Hence, } 300 = \frac{(4B + 30.8) \times [(4B + 30.8)/(B + 15.4)]^{2/3} \times (1/9000)^{1/2}}{0.012}$$

On solving this, $B = 30.6$ m.

9.7 DRAINAGE BEHIND LINING

When there is a build up of water pressure behind the lining, failure of the lining does occur. Causes of this water pressure are : (a) high water table; (b) saturation by the canal water followed by drawdown of the canal; or (c) saturation by continuous rainfall. If the embankment soil is pervious and sufficient free board has been provided in the lining, saturation by canal water and rainfall would be of short duration; as such the provision of drainage arrangement is not necessary. Drainage has to be provided where the water table may rise to above the canal bed level and where the banks are formed of soil having a low permeability.

The drainage is provided in the form of a continuous filter blanket or a series of tranverse and longitudinal drains beneath the lining (Figure 9.12). The drains normal to the flow direction, or transverse drains, would be filled with gravel conforming to the filter criteria and would discharge into the drains along the flow direction or longitudinal drains consisting of open jointed or French drains enclosed by filter material. Where the water table remains below canal bed, and if levels allow, the water from the longitudinal drains could be discharged by cross drains below the bank. The longitudinal drains are provided with flap or ball valves opening upwards at intervals. These valves open up whenever the pressure behind the lining builds up, discharge the drainage water into the canal and relieve the pressure behind the lining.

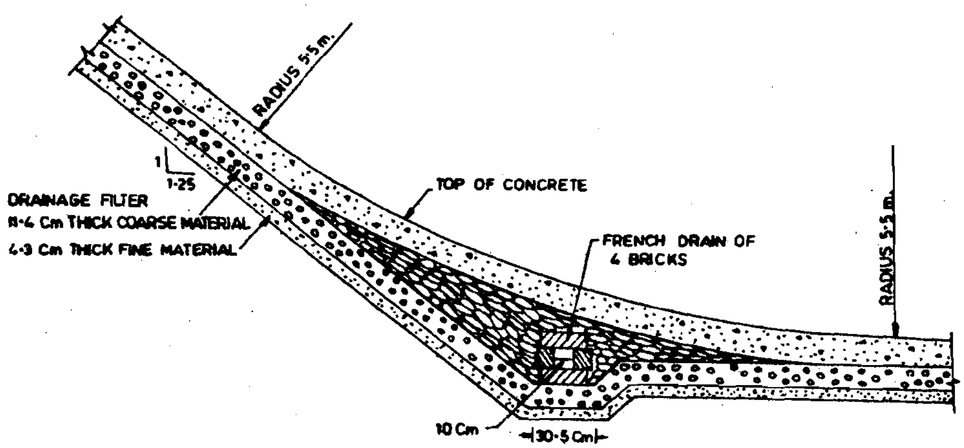

Figure 9.12 : A Typical Drainage Arrangement behind a Lining

9.8 COST OF LINING

The economics of a lined canal is worked out as follows :

Let C = cost of dressing the banks for lining and cost of lining, and also including any saving resulting from the smaller cross section (due to allowing higher velocity of flow) and hence smaller area of land, to be acquired (Rs/sq m).

This saving will be available on canals newly excavated and lined to the required section but not on lining of existing unlined canals,

s = seepage losses in unlined canal, m^3/sq m of wetted perimeter per day of 24 hours,

S = seepage losses in lined canal, m^3/sq m of wetted perimeter per day of 24 hours,

p = wetted perimeter of unlined section, (m),

P = wetted perimeter of lined section, (m),

T = total perimeter of lining, (m), that includes the unwetted portion (that is there due to free board),

d = number of running days of the canal per year,

W = value of water saved, (Rs/m^3),

L = length of canal, (m),

Y = life of canal, (years),

M = annual saving in operation and maintenance, (Rs), and

B = annual estimated value of benefits for the length of canal under consideration (Rs). These will include prevention of waterlogging, reduced cost of drainage for adjoining lands, reduced risk of canal breach, and so on.

The annual value of water lost on account of seepage from an unlined canal section

$$= p\,L\,s\,d\,W. \qquad \ldots (9.6)$$

The annual saving in the value of water not lost by seepage

$$= (p\,L\,s\,d\,W - P\,L\,S\,d\,W)$$

$$= L\,d\,W(p\,s - P\,S) \qquad \ldots (9.7)$$

Total annual benefits derived by lining the canal

$$= \left(L\,d\,W(p\,s - P\,S) + B + M\right) \qquad \ldots (9.8)$$

The additional capital expenses on constructing a lined canal

$$= T\,L\,C \qquad \ldots (9.9)$$

One can, thus, perform benefit-cost analysis of the project.

The cost of the lining should be recovered during the useful life of the lining. If an instalment a is deposited for each year for Y years, the total amount accumulated at the end of Y years will be (i, being the rate of interest),

$$= a\left((1+i)^Y + (1+i)^{Y-1} + \ldots + (1+i)^1\right) \qquad \ldots (9.10)$$

$$= \frac{a\left((1+i)^Y - 1\right)}{i} \qquad \ldots (9.11)$$

The present worth of this accumulated sum should be equal to the capital investment (i.e., initial cost), R (= TLC, in the present case). Therefore,

$$R = \frac{a\left((1+i)^Y - 1\right)}{i\,(1+i)^Y} \qquad \ldots (9.12)$$

The ratio of the annual instalment, a, to the capital investment, R, is called the 'capital recovery factor', r, so that $a = r\,R$. From this we have :

$$r = a/R = \frac{i\,(1+i)^Y}{\left((1+i)^Y - 1\right)} \qquad \ldots (9.13)$$

The values of r calculated from Equation (9.13) have been given in Table 9.4 for some common values of i and Y. The value of a derived from Equation (9.13) should be equal to or more than the value given by $a = r \times TLC$. Alternatively, we can assess the usefulness of a project taking the value of a as $r \times TLC$, the value, W, of additional water saved due to lining can be computed from Equation (9.8).

Table 9.4 : Capital Recovery Factors (r)

Years	Interest rate, i, in per cent					
	4	6	8	10	12	14
10	0.12329	0.13587	0.14903	0.16275	0.17698	0.19171
15	0.08994	0.10296	0.11683	0.13147	0.14682	0.16281
20	0.07358	0.08718	0.10185	0.11746	0.13388	0.15099
25	0.06401	0.07823	0.09368	0.11017	0.12750	0.14550
30	0.05783	0.07265	0.08883	0.10608	0.12414	0.14280
35	0.05358	0.06897	0.08580	0.10369	0.12232	0.14144
40	0.05052	0.06646	0.08386	0.10226	0.12130	0.14075
45	0.04826	0.06470	0.08259	0.10139	0.12074	0.14039
50	0.04655	0.06344	0.08174	0.10086	0.12042	0.14020

SAQ 3

What are the factors affecting the economics of a lined channel? Give a few (at least two) practical examples.

9.9 SUMMARY

Lining of a canal basically reduces the seepage losses, and allows to improve the command of the project. Water tightness, hydraulic efficiency, strength and durability are the main sought after characteristics of a lining material besides its cost considerations. Various types of lining (material wise) are available for use with characteristic advantages and disadvantages. A simple design procedure leads to the determination of the dimensions of a lined section, allowing a greater velocity of flow in it depending upon the Manning's coefficient relevant to the lining material. It is desirable to provide drainage behind the lining to relieve pore pressures on the material whenever situation necessitates such a measure.

Cost of providing a lining has to be balanced against the benefits (reduction in land requirement, saving in water, etc.) that are to accrue. Therefore, attractive rate of return, and the rate of interest are important factors in this context.

9.10 KEY WORDS

Drainage Behind Lining : The reduction of back pressure on the lining on account of emptying the canal by means of removal of water accumulated behind the lining.

Durability : The ability of the lining to withstand the effects of weathering and chemical attack.

Earth Materials in Lining : Earth used by compacting it or mixing cement with the soil and using as a material for lining canals.

Hydraulic Efficiency	:	The discharging capacity of a canal considering the coefficient of roughness (n) of the canal section.
Initial Cost and Recurring Maintenance Costs	:	The cost of the lining at the time of laying it and the subsequent cost for maintaining it on an annual basis.
Joints	:	These are provided in concrete lining panels to allow for contraction of the lining and also to facilitate construction.
Laying of Concrete Lining	:	Placement of concrete lining on slopes and bed of a canal.
Lined Sections	:	Canals provided with some hardened material to have a more hydraulically efficient canal section.
Prefabricated Light Weight Membrane Lining	:	Asbestos, jute or other organic fibres coated with bitumen, is laid on the subgrade and covered with soil and gravel.
Resistance to Attack	:	This is the requirement of a lining to be able to last long after installation. There may be chemical and rodent attacks that have to be resisted.
Shotcrete or Gunite Lining	:	A type of lining in which a mixture of cement, sand and aggregates is sprayed on to the surface with the help of compressed air to form the lining.
Stone Blocks	:	Undressed stones set in cement mortar are used in hilly areas to form the lining of canals.
Subgrade Preparation	:	It is done to prevent the cracking of a concrete lining on account of settlement of the subgrade.
Undressed Stones	:	Boulders that are not cut to any particular shape, size or finish so that to reduce the time, and effort in cutting the stone.

9.11 ANSWERS TO SAQs

Refer the relevant portions of the text, and relevant references given under the section 'Further Reading' at the end of the block.