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LINING AND MAINTENANCE OF CANALS

ADVANTAGES AND DISADVANTAGES OF LINING

a) **Advantages**: The following are the main advantages of lined canals over unlined canals:

1. **Prevention of loss of water:** Valuable water is saved by reducing seepage losses.
2. **Prevention of waterlogging:** the adjacent land is "prevented from waterlogging due to seepage of water from the canal.
3. **Low maintenance cost:** the maintenance cost of a lined canal is less compared to that of an unlined canal.
4. **Less breaches:** the possibility of breaching of the canal is considerably decreased, as the section is more stable and strong.
5. **Smaller cross-sectional area:** because higher velocity is permitted, the cross-sectional area of a lined canal is much smaller than that of an unlined canal.
6. **Saving in canal structures:** because of smaller cross-section of the canal, there is saving in the cost of earthwork, canal structures, and other allied works.
7. **Saving in land:** because of smaller bed widths, the cost of land is less.
8. **Less silting:** because of higher velocities, silting is less.
9. **Flatter slopes:** the bed slope of a lined canal is considerably less than that of an unlined canal. Because of flatter slopes in the bed, there is an increase of the commanded area. In the case of hydel channels, there is a larger useful head at the powerhouse.
10. **No scouring:** Because of hard lined surface, there is no scouring of the canal bed and sides, which normally occurs in an unlined canal.
11. **Reduction of weed growth:** there is a reduction of the weed growth. The transpiration losses are also decreased.
12. **Low evaporation loss:** Because of higher velocity and smaller exposed area, the evaporation losses are low.
13. **Increase of the value of land:** the value of the land is increased because the waterlogging problem is considerably reduced.
14. **Less salt problem:** the canal water does not come in contact with harmful salts present in the natural soil, and, therefore, the salt problem is reduced to some extent.
15. **Better operation:** the lined canal has a stable section, which is easy to operate.

b) **Disadvantages**: A lined canal has the following disadvantages as compared to an unlined canal.

1. **High initial cost** the initial cost of a lined canal is high.
2. **Difficult to repair** if the lining is damaged, it is difficult to repair.
3. **Difficult to shift the outlets** as the lining is strong and permanent; it is difficult to shift the canal outlets at a later stage.

4. **Less additional safety** as a lined canal does not have inside berms, the additional safety provided by the berms in the case of unlined to the vehicular and pedestrian traffic is absent.

TYPES OF LINING

Various types of lining can be grouped into the following categories:

a) Exposed lining with a hard surface. This type of lining has an exposed surface, which is quite hard. This is further classified into the following types:

1. In-situ concrete lining. 2. Precast concrete lining

3. Shot Crete lining. 4. Cement mortar lining

5. Lime concrete lining. 6. Brick tile lining or burnt clay tile lining

7. Stone block or undressed stone boulder lining. 8. Asphaltic concrete lining.

b) Buried membrane lining. This type of lining is buried below the channel surface. It is further divided into the following types:

1. sprayed-in-place asphalt membrane lining.

2. Prefabricated asphaltic membrane lining.

3. Polythene film and synthetic rubber membrane lining.

4. Bentonite and clay membrane lining.

5. Road oil lining.

c) Earth lining: This type of lining uses the soil as a lining material it is further divided into the following types:

1. Thin compacted earth lining. 2. Thick compacted earth lining

3. Loosely placed earth lining. 4. Stabilized soil lining

5. Bentonite soil lining. 6. Soil-cement lining.

d) Porous lining: This type of lining is made of a porous material a brief description of the various types of lining is given in the following sections.

IN-SITU CONCRETE LINING

In-situ concrete is the most commonly used lining. It consists of a layer of cement concrete placed on a well-prepared and compacted subgrade (soil) in the bed and sides of the channel.

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Advantage of concrete lining

1. It is quite impermeable and seepage losses are considerably reduced.
2. It is quite strong and durable.
3. It has a low coefficient of rugosity and high hydraulic efficiency. Hence, high velocity can be permitted.
4. High velocities prevent silting tendency. Evaporation losses are also reduced.
5. It permits fast construction by mechanical equipment.
6. The maintenance cost is low.
7. It is immune to weed growth.
8. It can be used in different thicknesses according to the capacity of the channel.
9. There is no need of plastering the lined surface.
10. Economy can be effected by using lean proportions (1:4:8) and by partial replacement of cement with pozzolana (surkhi).

Disadvantages of concrete lining

1. The initial cost is quite high.
2. It is prone to cracking due to temperature changes and shrinkage.
3. Repair is costly and difficult. Alteration of the canal outlets is quite difficult.
4. Because of relatively small thickness, it has limited resistance to external hydrostatic pressure after rapid drawdown.
5. It is susceptible to adverse subgrade conditions.
6. Skilled labour, and elaborate concrete mixing plants and transportation equipment are needed
7. Strict quality control is required to ensure concrete of proper grade, consistency and strength.
8. Under very high velocities, the fine material in the concrete is eroded, leaving behind a coarse surface with a high rugosity coefficient.

PRECAST CONCRETE LINING

In precast concrete lining, precast concrete slabs of the sizes $50\ cm\ \times\ 50\ cm\ \times\ 5\ cm\ and\ 50\ cm \times\ 25\ cm\ \times\ 5\ cm$ are commonly used.

Advantages of precast concrete lining over in-situ concrete lining

1. Precast concrete slabs are manufactured under controlled conditions. Therefore, the quality of concrete is good. These slabs provide a better, more impervious and durable lining than in-situ concrete lining.
2. Precast concrete lining involves less site operations. Therefore, the speed of construction is quite fast.
3. Precast concrete slabs can be manufactured on a mass scale. The precast concrete lining is usually cheaper than the in-situ concrete lining.

4. Precast concrete slabs can be manufactured during non-working season. These slabs are sometimes placed all along the canal for curing purposes after casting. Thus the cost of curing is reduced.
5. The shrinkage cracks are less because the slabs are of small size.
6. If the lining is damaged due to settlement of subgrade, it can be easily repaired; whereas in the case of r a-situ concrete lining, it is very difficult to repair.
7. There the ground water table in high, water pressure is released through the joints between these labs.

Disadvantages

1. Seepage losses are generally more in the case of precast concrete lining.

2. Transportation of precast slabs is costly and time-consuming. Moreover, breakage of slabs also occurs during transportation.

SHOTCRETE LINING

In shotcrete lining, cement mortar is forced under pressure through a nozzle on the surface of the subgrade of the channel. Generally, cement mortar 1:4 is applied pneumatically (i.e. by compressed air) through a nozzle. The pneumatically applied mortar is called shotcrete and hence the lining is known as shotcrete lining

Advantages

1. There is no necessity of fine dressing of the subgrade because shotcrete lining can be placed even on irregular surfaces. This is specially useful in rock cuts.

2. The equipment required for shotcrete is quite light and mobile. It is particularly suitable for small and widely scattered jobs.

3. Shotcrete is useful for resurfacing of badly cracked and leaky but structurally sound old cement concrete lining.

Disadvantages

1. Shotcrete lining is costlier than concrete lining.

2. It is less durable than the concrete lining of the usual thickness. It gives satisfactory service only for 20 years or so.

CEMENT MORTAR LINING

In cement mortar lining, a layer of cement mortar (1:3) of uniform thickness is laid on a properly compacted subgrade. The usual thickness of the cement mortar lining is 2.50 cm.

Cement mortar lining is not commonly used, as it is quite expensive. Moreover, it is less durable than cement concrete lining. However, a 2.5 cm thick cement mortar lining is sufficient to reduce seepage losses by about 75%.

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LIME CONCRETE LINING

Lime concrete lining consists of hydraulic lime, sand and coarse aggregate mixed in a suitable proportion.

Lime concrete lining is not as impervious as cement concrete lining. It is rarely used in practice.

BRICK TILE LINING

The brick tile lining, also called burnt clay tile lining, consists of either a single layer or a double layer of brick tiles laid in cement mortar. The size of the tiles is generally restricted to $30\ cm\ \times\ 15\ cm\ \times\ 5\ cm$ for convenience of handling.

Advantages of brick tile lining over cement concrete lining.

1. Brick tile lining is usually economical in initial cost.
2. No elaborate equipment is needed for laying tiles.
3. The tiles can be laid by ordinarily masons.
4. Transportation cost is usually small, as kilns for burning the tiles can be established near the site.
5. Expansion joints are not required, as the shrinkage is practically eliminated and the coefficient, of expansion of tiles is very small.
6. The thickness of lining is uniform because it is governed by the thickness of tiles.
7. The rounded sections of the channel can be easily lined without the use of a formwork.
8. If there is any settlement of the subgrade, numerous small cracks are developed in the mortar layer between the tiles, but the seepage loss is insignificant. In case of large settlement, the small damaged area can be easily repaired.

Disadvantages of brick tile lining over cement concrete lining.

1. Brick tile lining is relatively more previous than cement concrete lining.
2. The maintenance cost is high.
3. It has relatively lower resistance to abrasion.
4. It cannot be done mechanically. It is a relatively slow process.
5. It cannot be used where suitable materials for manufacture of tiles are not locally available. Brick title lining is commonly used at places where suitable clay for making brick tiles is easily available and it is economical.

STONE BLOCK LINING (OR BOULDER LINING)

Stone block lining consists of a layer of undressed stones (or boulders) set in 1:6 cement mortar

Stone block lining has better wearing resistance than brick tile lining. It is more suited to steep channels, especially in hilly areas. It is also more impervious than brick tile lining. It is quite economical where good quality stone is easily available near the site.

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ASPHALTIC CONCRETE LINING

Asphaltic concrete lining is similar to cement concrete lining. The asphaltic concrete consists of a mixture of asphalt, cement and graded aggregates, and hence it is also known as *asphaltic* cement concrete.

Advantages

1. Asphaltic concrete lining is relatively flexible and has greater ability to withstand settlements in the subgrade.
2. It can be used in place of cement concrete lining wherever it is cheaper because of low cost of asphalt.
3. It can be used for the repairs of cement concrete lining by laying a resurfacing layer of asphaltic concrete.

Disadvantages

1. It has low resistance to external hydrostatic pressure developed due to seepage.
2. There is a danger of sliding or slipping during hot weather.
3. The velocity in asphaltic concrete lined channels is usually limited to 1.5 m/s
4. The coefficient of rugosity (N) is high if there is no special surface finish.
5. It permits certain type of weed growth which may cause its puncturing.

BURIED MEMBRANE LINING

Buried membrane lining are buried beneath the channel surface. The buried membrane linings are of the following types:

1. Sprayed-in-place asphaltic membrane lining
2. Prefabricated asphaltic membrane lining.
3. Polyethelene film and synthetic rubber membrane lining.
4. Bentonite clay membrane lining.
5. Road oil lining.

A brief description of these linings is given below:

1. **Sprayed-in-place asphaltic membrane lining:** This type of lining consists of a thin layer, about 6mm thick, of a special high softening-point asphalt sprayed in place at a high temperature of about 150°C to 20O°C on a properly prepared subgrade to form an impervious barrier. The asphaltic layer is covered with a 30 cm thick layer of earth and gravel to protect it from damage and weather.

Advantages

1. It provides an effective and relatively cheap method of seepage control in channels.
2. It can be easily laid even in cold and wet weather.
3. It is quite flexible and readily adjusts to the settlements in subgrade.

Disadvantages

1. There is no decrease in the coefficient of rugosity because the exposed surface consists of earth.
2. High velocity cannot be permitted.
3. The useful life of lining is limited.
4. It requires special equipment and trained workers for spraying of hot asphalt.
2. **Prefabricated asphaltic membrane lining:** this type of lining consists of a prefabricated asphaltic membranes available in rolls. The membrane is spread directly on the prepared subgrade and covered with protective earth.

A prefabricated asphaltic membrane lining has the same advantages and disadvantages as those in sprayed-in-place asphaltic membrane lining. However, there is no need of special equipment and skilled workers in this case. Prefabricated asphaltic membrane lining is quite durable. The membranes can be easily-handled and transported.

3. **Polyethylene film and synthetic rubber membrane lining.** In this type of lining, a polyethylene film or a synthetic rubber membrane is laid on the subgrade and a protective cover of earth is place it.
4. **Bentonite clay membrane lining.** Bentonite is a type of clay which contains a large percentage of the mineral montomorrillonite
   This type of lining is quite economical if bentonite is easily available.
5. **Road oil lining.** in this type of lining, road oil is sprinkled over the subgrade in a thickness of about 1.5 mm.

EARTH LINING

In earth lining, soil is used as a lining material. The following types of earth linings are sometimes used.

1. **Thin-compacted earth lining:** In this type of lining, a layer of clayey soil, 15 to 30 cm thick, is placed on the subgrade and thoroughly compacted.
2. **Thick compacted earth lining:** This-type of lining is similar to the thin-compacted earth lining, but the thickness of lining is more. The thickness varies from $30\ cm$ to $60\ cm$ at the bed and from $60\ cm$ to $90\ cm$ on the sides of the channel. The lining is thoroughly compacted in layers.
3. **Loosely placed earth lining:** In this type of lining, the clayey soil used as lining is not compacted. Suitable clayey soil is just spread over the bed and sides of the channel in layers up to a thickness of 30 cm.
4. **Stabilized soil lining:** In this type of lining, the stabilized soil is used in the bed and at the sides of the channel. The soil is stabilized and rendered impervious by the addition of specially treated resins and chemicals such as sodium silicate, sodium chloride, commercial resins, cement, lime, asphalt and petrochemicals.
5. **Bentonite clay lining:** In this type of lining, the bentonite clay is used as a lining material. The subgrade in the bed and at the sides of the channel is mixed in place with bentonite to form a $5\ to\ 10\ cm$ thick layer.

6. **Soil cement lining:** Soil cement is a mixture of soil and cement.

There are basically two types of soil cement lining.

(a) Compacted soil cement lining.

(b) Plastic soil cement lining.

POROUS LINING

Porous lining is usually provided in the head reaches of the main canal when the ground water table is higher than the bed level of the channel. The ground water in the subgrade passes throw the pores of the lining and, consequently, the external hydrostatic presser on the lining is released.

For laying the porous lining, the subgrade is properly prepared. The bed and sides are divided into suitable compartments. Not exceeding 15 m in any direction by constructing ribs of stone masonry or cement concrete. The ribs are generally rectangular in section. The thickness of ribs is equal to the combined thickness of the lining and filter.

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Water Management (water losses)

1. Absorption Losses
2. Percolation (or seepage) Losses
3. Evaporation Losses
4. Transpiration Losses

ABSORPTION LOSSES

Absorption losses occur because of absorption of water by soil surface canal wetted perimeter.

When the water table is at a considerable depth below the canal bed, the
Infiltrating the soil below
The canal bed in unable to reach the ground water reservoir below the table.
Absorption losses are independent of the seepage head. These losses depend upon the water head hc form the water level of the canal to the bottom of the saturated zone and the capillary head hc, for the soil at the boundary of the saturated zone and the capillary head hc, for the soil at the boundary the saturated zone. In general, absorption losses depend mainly upon the depth of water in the canal **X** type of soil.

PERCOLATION (OR) SEEPAGE LOSSES

Percolation losses are usually much greater than absorption losses. They may be as high as 3 times or more of the absorption losses whether losses will be by absorption or by percolation will depend primarily on the nature of soil strata and the level of the water table.

Both the absorption loss & percolation are loss initially large because the water is utilized for filing the pores of the soil. With the passage of time, the losses decrease & an equilibrium is finally reached. Moreover the silt carried by the canal water gats deposited in the canal & reduces the soil permeability & hence the seepage

Absorption & percolation losses from the canal mainly depend upon the following factors.

(i) Permeability of soil

The greater is permeability of the soil in the bed & banks of the canal, the greater are the losses.

(ii) Depth of water

The greater is the depth of water, in the canal, the greater the losses.

(iii) Velocity of water

The losses decrease with an increase in the velocity of flow in the channel.

(iv) Amount of silt

The losses decrease with an increase in the amount of silt carried by the canal.

(v) Temperature of water

The losses increase with an increase in temperature of water because permeability of the soil is increased.

(vi) Age of the channel

The losses are large in newly constructed channels and they reduce as silt deposited with the passage of time & a relatively impervious silt layer is formed.

(vii) Level of the channel bed

The losses depend upon the level of the channel bed w.r.t natural surface or ground level. The losses are more when the canal is in heavy filling.

(viii) Position of the water table

The losses depend upon the position of water table w.r.t the canal bed the losses are more when the water table is high.

EVAPORATION LOSSES

Evaporation losses depend upon the water surface area of the canal, relative humidity, wind velocity, temperature & various other factors. In hot & dry summer months, the evaporation losses are high, but they seldom exceed 10% of the total losses. Generally, evaporation losses is less Than 1% of the total water entering the canal head.