I CANAL

A canal is an artificial channel generally trapezoidal in shape constructed on the ground to carry water to the field either from the river of from a reservoir.

1.1 Canal Linings

- 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.
- Canal Lining is an impermeable layer provided for the bed and sides of canal to improve the life and discharge capacity of canal. 60 to 80% of water lost through seepage in an unlined canal can be saved by construction canal lining.

1.2 Types of Canal Linings

Canal linings are classified into two major types based on the nature of surface and they are:

1. Earthen type lining
2. Hard surface lining

1. Earthen Type lining

Earthen Type lings are again classified into two types and they are as follows:

i. Compacted Earth Lining

ii. Soil Cement Lining

i. Compacted Earth Lining

Compacted earth linings are preferred for the canals when the earth is available near the site of construction or In-situ. If the earth is not available near the site then it becomes costlier to construct compacted earth lining. Compaction reduces soil pore sizes by displacing air and water. Reduction in void size increases the density, compressive strength and shears strength of the soil and reduces permeability. This is accompanied by a reduction in volume and settlement of the surface. Proper compaction is essential to increase the stability and frost resistance (where required) and to decrease erosion and seepage losses.

ii. Soil Cement Lining

Soil-cement linings are constructed with mixtures of sandy soil, cement and water, which harden to a concrete-like material. The cement content should be minimum 2-8% of the soil by volume.

However, larger cement contents are also used.

In general, for the construction of soil-cement linings following two methods are used.

i.Dry-mix method

ii.Plastic mix method

For erosion protection and additional strength in large channels, the layer of soil-cement is sometimes covered with coarse soil. It is recommended the soil-cement lining should be protected from the weather for seven days by spreading approximately 50 mm of soil, straw or hessian bags over it and keeping the cover moistened to allow proper curing. Water sprinkling should continue for 28 days following installation.

2. Hard Surface Canal Linings

It is sub divided into 4 types and they are

i. Cement Concrete Lining

ii. Brick Lining

iii. Plastic Lining

iv. Boulder Lining

i. Cement Concrete Lining

Cement Concrete linings are widely used, with benefits justifying their relatively high cost. They are tough, durable, relatively impermeable and hydraulically efficient. Concrete linings are suitable for both small and large channels and both high and low flow velocities. They fulfill every purpose of lining.

There are several procedures of lining using cement concrete

i. Cast in situ lining

ii. Shortcrete lining

iii. Precast concrete lining

iv. Cement mortar lining

ii. Brick Lining

In case of brick lining, bricks are laid using cement mortar on the sides and bed of the canal. After laying bricks, smooth finish is provided on the surface using cement mortar.

iii. Plastic Lining

Plastic lining of canal is newly developed technique and holds good promise. There are three types of plastic membranes which are used for canal lining, namely:

a) Low density poly ethylene

b) High molecular high density polythene

c) Polyvinyl chloride

The advantages of providing plastic lining to the canal are many as plastic is negligible in weight, easy for handling, spreading and transport, immune to chemical action and speedy construction. The plastic film is spread on the prepared sub-grade of the canal. To anchor the membrane on the banks‘V trenches are provided. The film is then covered with protective soil cover.

iv. Boulder Lining

This type of lining is constructed with dressed stone blocks laid in mortar. Properly dressed stones are not available in nature. Irregular stone blocks are dressed and chipped off as per requirement. When roughly dressed stones are used for lining, the surface is rendered rough which may put lot of resistance to flow. Technically the coefficient of rugosity will be higher. Thus the stone lining is limited to the situation where loss of head is not an important consideration and where stones are available at moderate cost.

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. Seepage Reduction

The main purpose behind the lining of canal is to reduce the seepage losses. In some soils, the seepage loss of water in unlined canals is about 25 to 50% of total water supplied. The cost of canal

lining is high but it is justifiable for its efforts in saving of most of the water from seepage losses. Canal lining is not necessary if seepage losses are very small.

2. Prevention of Water Logging

Water logging is caused due to phenomenal rise in water table due to uncontrolled seepage in an unlined canal. This seepage effects the surrounding ground water table and makes the land unsuitable for irrigation. So, this problem of water logging can be surely prevented by providing proper lining to the canal sides.

3. Increase in Commanded Area

Commanded area is the area which is suitable for irrigation purpose. The water carrying capacity of lined canal is much higher than the unlined canal and hence more area can be irrigated using lined canals.

4. Increase in Channel Capacity

Canal lining can also increase the channel capacity. The lined canal surface is generally smooth and allows water to flow with high velocity compared to unlined channel. Higher the velocity of flow greater is the capacity of channel and hence channel capacity will increase by providing lining. On the other side with this increase in capacity, channel dimensions can also be reduce to maintain the previous capacity of unlined canal which saves the cost of the project.

5. Less Maintenance

Maintenance of lined canal is easier than unlined canals. Generally there is a problem of silting in unlined canal which removal requires huge expenditure but in case of lined canals, because of high velocity of flow, the silt is easily carried away by the water.

In case of unlined canals, there is a chance of growth of vegetation on the canal surface but not in case of lined canals. The vegetation affect the velocity of flow and water carrying capacity of channel. Lined canal also prevents damage of canal surface due to rats or insects.

6. Safety against Floods

A line canal always withstand against floods while unlined canal may not resists and also there is chance of occurring of breach which damages the whole canal as well as surrounding areas or fields. But among the all concrete canal linings are good against floods or high velocity flows.

1.2 Kennedy's Silt Theory

RG Kennedy investigated canals systems for twenty years and come up with a Kennedy's silt theory. The theory says that, the silt carried by flowing water in a channel is kept in suspension by the eddy current rising to the surface. The vertical component of the eddy current tries to move sediment up whereas sediment weight tries to bring it down. Therefore, if adequate velocity available to create eddies so as to keep the sediment just in suspension silting will be prevented.

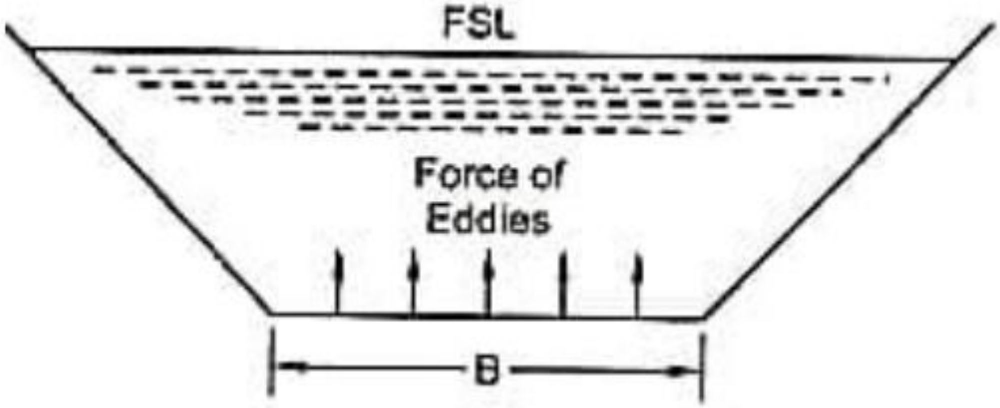

Fig.1: Eddies force according to Kennedy's silt theory

1.2.1 Assumptions regarding Kennedy's Silt Theory

1. The eddy current is generated because of friction between flowing water and the roughness of the canal bed.
2. The quality of the suspended silt is proportional to bed width.
3. The theory is applicable to those channels which are flowing through the bed consisting of sandy silt or same grade of silt.

Critical velocity based on Kennedy's Silt Theory

Critical velocity is the mean velocity which will just make the channel free from silting and scouring. The velocity is based on the depth of the water in the channel. The general form of critical velocity is as follow:

$$Vo = C\,D^{n} \text{----------------(1)}$$

Where

Vo = Critical velocity

D = full supply depth

C & n: Constants which found to be 0.546 and 0.64, respectively.

Thus, Equation 1 rewritten as follow:

$$Vo = 0.546\,D^{0.64} \text{--------------(2)}$$

Moreover, Equation 2 further improved upon realization that silt grade influences critical velocity.

So, a factor termed as critical velocity ratio introduced and the equation became as follows:

$$Vo = 0.546\ m\ D^{0.64} \text{ --------------(2)}$$

Where

m: critical velocity ratio which equal to actual velocity (V) divided by critical velocity (Vo), value of m provided in Table 1.

Table 1 Values of m based on the type of silt

Channel lining	N values
Earth	0.0225
Masonry	0.02
Concrete	0.013 to 0.018

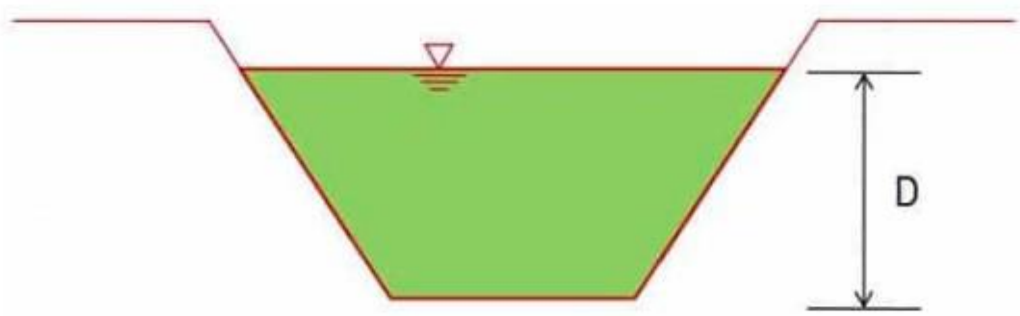

Fig.2: Depth of water in canal

Limitations of Kennedy's Silt Theory

1. Trial and error method used for the canal design using Kennedy's Silt Theory.
2. There is no equation for bed slope assessment, so the equation developed by Kutter used to compute bed slope.
3. The ratio of channel width (B) to its depth (D) has no significance in Kennedy's Silt Theory.
4. There is not perfect definition for salt grade and salt charge.
5. Complex phenomenon of silt transportation is not fully accounted and only critical velocity ratio (m) concept is considered sufficient.

Procedure of Canal design using Kennedy's Silt Theory

There are two cases of canal design using Kennedy's Silt Theory dependent on the given data. Both cases presented below:

Case 1

The following data shall be available before hand:

discharge (Q), rugosity coefficient (N), Critical velocity ratio (m) and bed slope of the channel (s).

1. Assume suitable full supply depth (D).
2. Then, find the mean velocity by using Kennedy's equation (Equation 3).
3. After that, find the area of cross section by using continuity equation:

$$Q=A\ V$$

Where:

Q: Discharge

A: cross section area

V: mean velocity computed in step 2

4. Assume the shape of channel section with side slopes (0. 5V:1H)
5. Find out the value of base width of channel (B).
6. Then, find the perimeter of the channel (P). Which helps to find out the hydraulic mean depth of channel (R).

$$R = A/P \qquad \textit{Equation 5}$$

Where:

R: hydraulic mean depth

A: canal cross section area

P: perimeter of the section

7. Finally, calculate the mean velocity (V) using kutter's formula:

$$V = \left(\frac{1/N(23+0.00155/s)}{1+(23+0.00155/s)(N/\sqrt{R})}\right)\sqrt{Rs} \quad \textit{Equation 6}$$

Where:

N: rugosity coefficient based on type of canal lining material. Table 2 provide N values for different lining condition.

S: bed slope as 1 in ‘n’.

Both the values of V computed using equation 3 and V computed employing equation 6 must be the same. Otherwise repeat the above procedure by assuming another value of D.

Generally, the trial depth is assumed between 1 m to 2 m. If the condition is not satisfied within this limit, then it may be assumed accordingly.

Table 2 N values based on the channel lining material

Channel lining	N values
Earth	0.0225
Masonry	0.02
Concrete	0.013 to 0.018

Case 2

When discharge (Q), rugosity coefficient (N), Critical velocity ration (m) and B/D ratio are given.

1. Assume B/D = X
2. By using the Kennedy’s equation find “V” in terms of D.
3. Find the area of cross section of the channel in terms of D2.
4. By using continuity Equation 4, find the value of D. and then Find the base width (B).
5. Find hydraulic mean depth (R) with Equation 5.
6. Finally, find the value of “V” using Equation 3.

7. Substitute the value of V in step 6 in Equation 6 will gives the longitudinal slope of the channel
(S). This case will done by trial and error method.

1.3 Lacey's Silt Theory of Canals

Lacey investigated the stability conditions of different alluvial channels and came up with Lacey's silt theory which explains about the different regime conditions of a channel such as true regime, initial regime, and final regime and the design procedure of canal.

Lacey stated that a channel may not be in regime condition even if it is flowing with non-scouring and non-silting velocity.

Therefore, he distinguished three regime conditions as follows :

1. True regime
2. Initial Regime
3. Final Regime

1. True regime

A channel is said to be in regime condition if it is transporting water and sediment in equilibrium such that there is neither silting nor scouring of the channel. But according to Lacey, the channel should satisfy the following conditions to be in regime condition.

1. Canal discharge should be constant.
2. The channel should flow through incoherent alluvium soil, which can be scoured as easily as it can be deposited and this sediment should be of the same grade as is transported.
3. Silt grade should be constant.
4. Silt charge, which is the minimum transported load should be constant.

If the above conditions are satisfied, then the channel is said to be in true regime condition. But this is not possible in actual practice. Hence lacey defined two other conditions which are initial and final regime conditions.

2. Initial Regime

A channel is said to be in initial regime condition when only the bed slope of channel gets affected by silting and scouring and other parameters are independent even in non-silting and non-scouring velocity condition. It may be due to the absence of incoherent alluvium. According to Lacey's, regime theory is not applicable to initial regime condition.

3. Final Regime

If the channel parameters such as sides, bed slope, depth etc. are changing according to the flow rate and silt grade then it is said to be in final regime condition. The channel shape may vary according to silt grade as shown in the figure below :

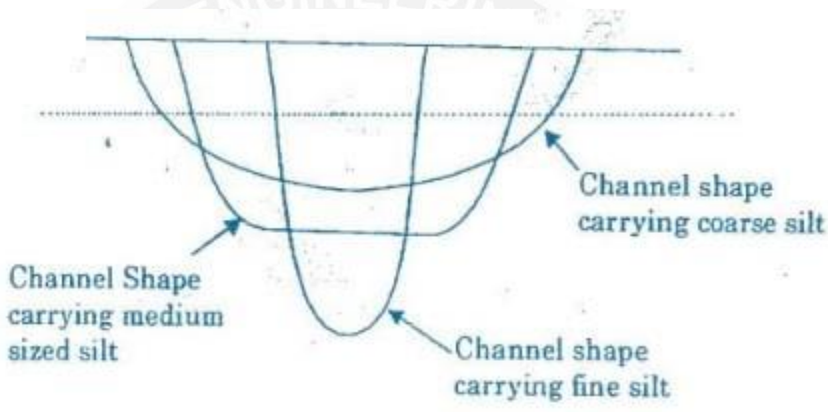

Fig 2: Channel Shape vs Silt Grade

Lacey's specified that the regime theory is valid for final regime condition only and he also specified that semi-ellipse is the ideal shape of regime channels.

Canal design using Lacey's Silt Theory

1. According to lacey's, the design procedure to build canal is as follows :
2. Canal discharge (Q) and mean particle size (dm) should be known.
3. From the mean size or diameter of the particle (dm), silt factor is first calculated using the below expression :

$$Silt\ factor, f = 1.76\sqrt{d_m}$$

4. Silt factor values for different types of soils are tabulated here.

S.No	Soil Type	Silt Factor, f
1	Fine silt	0.5 – 0.7
2	Medium silt	0.85
3	Standard silt	1
4	Medium sand	1.25
5	Coarse sand	1.5

5. Using discharge and silt factor, velocity (V) can be calculated by the expression as follows :

$$Velocity\ of\ flow, V = [\frac{Qf^2}{140}]^{1/6}$$

6. After attaining the velocity of canal flow, find the area of the canal by dividing discharge with velocity. Also, find the mean hydraulic depth (R) of the canal and wetted perimeter (P) of the canal.

$$Area = \frac{Q}{V}$$

$$Hydraulic\ Mean\ Depth, R = \frac{5V^2}{2f}$$

$$Wetted\ Perimeter, P = 4.75\sqrt{Q}$$

7. Assume the bed slope (S) value or find by substituting the values of silt factor and canal discharge in the following formula :

$$Bed\ slope, S = \frac{f^{5/3}}{3340Q^{1/6}}$$

Drawbacks of Lacey's Silt Theory

•Lacey did not explain the properties that govern the alluvial channel.

•In general, flow is different at bed and sides of the channel which requires two different silt factors but Lacey derived only one silt factor.

•The semi-elliptical shape proposed by Lacey as the ideal shape of the channel is not convincing.

•Lacey did not consider the silt concentration in his equations.

•Attrition of silt particles is ignored by Lacey.

•Lacey did not give proper definitions for the silt grade and silt charge.

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