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.

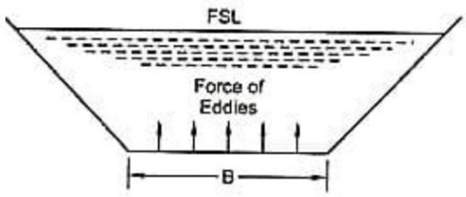

Fig.1: Eddies force according to Kennedy's silt theory

Assumptions regarding Kennedy's Silt Theory

The eddy current is generated because of friction between flowing water and the roughness of the canal bed.

The quality of the suspended silt is proportional to bed width.

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:Where

$Vo = C D^n$-----------------(1)

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:

$Vo = 0.546 D^{0.64}$---------------(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:

$Vo = 0.546 m D^{0.64}$---------------(2)
Where
m: critical velocity ratio which equal to actual velocity (V) divided by critical velocity (Vo), value

of m provided in Table 1.

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

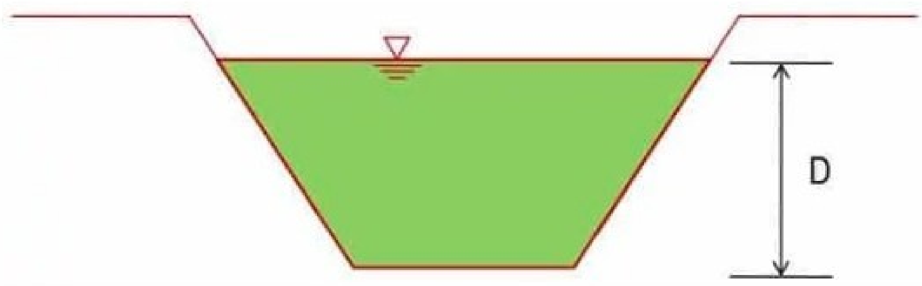

Fig.2: Depth of water in canal

Limitations of Kennedy's Silt Theory

Trial and error method used for the canal design using Kennedy's Silt Theory.

There is no equation for bed slope assessment, so the equation developed by Kutter used to compute bed slope.

The ratio of channel width (B) to its depth (D) has no significance in Kennedy's Silt Theory.

There is not perfect definition for salt grade and salt charge.

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:Where: Q=A V

Q: Discharge

A: cross section area

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).

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

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.

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.

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.

2. 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 :

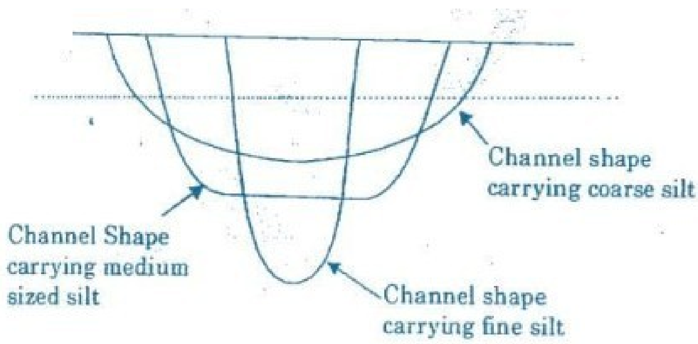

Fig 2: Channel Shape vs Silt Grade

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

According to lacey's, the design procedure to build canal is as follows :

Canal discharge (Q) and mean particle size (dm) should be known.

From the mean size or diameter of the particle (dm), silt factor is first calculated using the below expression :

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

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

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

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

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.

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

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

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

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.