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Ranga Raju and Misri's simplified method

They also assume the side slope of 1:0.5

$$A = BD + 0.5D^2 = D^2(B/D + 0.5)$$

$$A = D^2(X + 0..5)$$

Where X is equal to B/D ratio

$$P = B + 2D\sqrt{1 + 0.5^2}$$

$$= D\ (X + 2.236)$$

$$R = \frac{A}{P} \qquad = \frac{D(X + 0.5)}{X + 2.236}$$

$$V = \frac{Q}{A} = \frac{Q}{D^2(X + 0.5)}$$

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad or \quad \frac{Q}{A} = \frac{1}{n}\ R^{2/3} S^{1/2}$$

$$\left(\frac{Q}{A}\right)^2 = \frac{1}{n^2}\ R^{4/3} S$$

$$S = \frac{Q^2 n^2}{A^2 R^{4/3}} = \frac{Q^2 n^2 [(X + 2.236)]^{4/3}}{[D^2(X + 0.5)]^{10/3}}$$

$$S = \frac{Q^2 n^2 (X + 2.236)^{4/3}}{D^{16/3} (X + 0.5)^{10/3}}$$

From Kennedy's Eq.

$$Q = V.A = 0.55\, m\ \ D^{0.64} \quad .(D^2(X + 0.5))$$

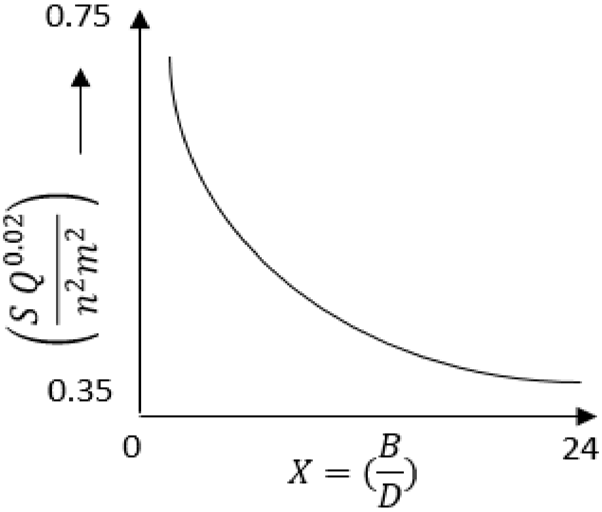
Or

$$D = \left[\frac{Q}{0.55\, m\, (X + 0.5)}\right]^{\frac{1}{2.64}} = \left[\frac{1.818\, Q}{m\, (X + 0.5)}\right]^{\frac{1}{2.64}}$$

$$S = \frac{Q^2 n^2 (X + 2.236)^{4/3}}{\left[\frac{1.818\,Q}{m\,(X + 0.5)}\right]^{2.02} (X + 0.5)^{10/3}}$$

$$\frac{S\,Q^{0.02}}{n^2 m^2} = 0.299 \quad \frac{(X + 2.236)^{4/3}}{(X + 0.5)^{1.313}}$$

∴ For the given values of S, Q, n and m, the value of X can be found by trial and error or by using the fig.



Exercise: Design a canal carrying a discharge of 25 m^3 /s by Ranga Raju and Misri's method assume m = 1.0, n = 0.0255 and S = 1/5000

Solution

$$\frac{S\,Q^{0.02}}{n^2 m^2} = 0.299 \quad \frac{(X + 2.236)^{4/3}}{(X + 0.5)^{1.313}}$$

$$\frac{2 \times 10^{-4} \times (25)^{0.02}}{(0.0225)^2 (1)^2} = 0.299 \frac{(X + 2.236)^{4/3}}{(X + 0.5)^{1.313}}$$

$$0.421 = 0.299 \;\frac{(X + 2.236)^{4/3}}{(X + 0.5)^{1.313}}$$

Solving by trial and error X = 6.00 or by using fig.

$$for \;\frac{S\,Q^{0.02}}{n^2 m^2} = 0.421 \qquad\qquad we\ have\ X = 6$$

$$D = \left[\frac{1.818\,Q}{m\,(X+0.5)}\right]^{\frac{1}{2.64}} = 2.09\,m$$

$$B = 2.09 \times 6 = 12.54\,m$$

$$V = \frac{Q}{D^2(X+0.5)} = 0.88\,m/s$$

$$check\ V = 055\,m\,D^{0.64}$$

$$= 0.55 \times 1 \times (2.09)^{0.64}$$

$$= 0.88\ m/s\ (o.k.)$$

Sediment transport theories

It has now been established that cross-section and bed slope of a true regime channel depend upon the following three independent variables:

1. Discharge (Q) carried by the channel.
2. Nature and grade of the sediment entering the channel such as the grain-size distribution, the shape of grains and the specific gravity of particles.
3. Quantity of sediment (or silt charge) entering the channel.

The silt theories discussed earlier consider only the first two variables and do not account for the third variable. The third variable, viz, the silt charge, is an important factor which considerably affects the channel design. For a satisfactory design, the silt charge should be considered. The various sediment theories consider the effect of silt charge on the design.

The sediment transported by a channel (or a stream) consists of the bed load and the suspended load.

1. The bed load is that portion of the sediment which moves on or near the bed of the channel. The movement of bed load is by rolling, sliding and saltation (i.e. small leaps).
2. The suspended load is that portion of the sediment which remains in suspension in the flowing water and does not touch the bed. The suspended load is kept in suspension by the turbulent eddies generated due to friction. The particles of the suspended load move freely through the flowing water.

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Estimation of bed load. The bed load can be estimated by the following two methods:

1. Sampler method   2. Analytical method

1. Sampler method. In this method, the samples of stream water are taken with the help of various types of samplers, such as box-type sampler and slot-type sampler the bed load is obtained after drying the sample and by determining the mass of dry solids. However, the samplers do not give a reliable value of the bed load. It is the usual practice to determine the bed load from the suspended load. Generally, the bed load is taken as 3 to 25% of the total suspended load, depending upon the nature of the bed materials. An average value of 10% is quite common.

2. Analytical method. Varies investigation have given analytical methods for the determination of the bed load. A brief introduction of the following theories is given below:

(i) Meyer-peter's equation   (ii) Einstein's equation

(i) Meyer-peter's equation Meyer-peter's equation, which is based on experimental work carried out at Federal Institute of Technology, Zurich, is

$$\left(\frac{Q_s}{Q}\right)\left(\frac{N^-}{N}\right)^{3/2} wSD = 0.047(w_s - w)\, d + 0.25\,(w/g)^{1/3}\,(q_s)^{2/3} \quad \dots (1)$$

Where Q_s is the actual discharge, Q is the discharge if the sides of the channel were frictionless, $N^-$is Manning's coefficient for plane bed, $N$is the actual value of the Manning's coefficient for rippled bed, w is the specific weight of water (kN/m^3), d is the mean grain diameter (m); S is the bed slope; D is the depth of flow (m), g is the acceleration due to gravity and q_s is the rate of bed load transport per unit width of the channel (kN/m/s).

The ratio Q_s/Q takes into account friction of the sides of the channel. If the sides friction is neglected, $Q_s/Q = 1.0$.

The values of N^- and N are obtained from Strickler's formula as follows:

$$N^- = (k_s)^{1/6}/24 \quad \dots (2)$$

and

$$N = (k)^{1/6}/24 \quad \dots (3)$$

Where $k_s$the effective is grain diameter (m) and k is the representative size (m) of roughness of the actual rippled bed. The values of N is also equal to Manning's coefficient. Its value normally varies from 0.020 to 0.025 for irrigation channels.

$$N = 0.0225\, f^{1/4} \qquad \ldots (4)$$

Bed shear, $\tau_b = (Q_s/Q)\, wDS$

Critical share stress, $\tau_c = 0.047\ (w_s - w)d$

Therefore, Eq (1) can be written as

$$\tau_b (N^{-}/N)^{3/2} = \tau_c + 0.25\ \ (w/g)^{1/3}\ (q_s)^{2/3}$$

Or $q_s = 47500\ \left[\tau_b (N^{-}/N)^{3/2} - \tau_c\right]^{3/2}$ kN/m/hr … (5)

Eq.(5) can be written in MKS units as

$q_s = 4700\ \left[\tau_b (N^{-}/N)^{3/2} - \tau_c\right]^{3/2}$ kg(f)/m/hr

Where $\tau_b$and τ_c are in kg(f)/m^2.

Illustrative Example A channel is 50m wide, 2.5m deep and has a bed slope of 1 in 4000. Determine the bed load transported by the channel by Meyer-Peter's equations. Neglect the side friction and take Manning's $N = 0.02$. The mean diameter of the material is 0.30mm and the representative size of the bed material for unrippled bed is 0.50 mm.

Solution From Eq. (2),

$N^{-} = (k_s)^{1/6}/24 = (0.5 \times 10^{-3})^{1/6}/24 = 0.0117$

As side friction is neglected, $Q_s/Q = 1.00$

From Eq. (5) $q_s = 47500\ \left[\tau_b (N^{-}/N)^{3/2} - \tau_c\right]^{3/2}$

$\tau_b = wDS = 9.81 \times (1/4000) \times 2.5 = 6.13 \times 10^{-3}$

$N^{-}/N = 0.0117/0.02 = 0.585$

$\tau_c = 0.047\ (w_s - w)d = 0.047(2.65 - 1.00) \times 9.81 \times 0.3 \times 10^{-3}$

$= 2.28 \times 10^{-4}$

Subtracting the above values in Eq. (a).

$$q_s = 47500\left[6.13 \times 10^{-3}\ (0.585)^{3/2} - 2.28 \times 10^{-4}\right]^{3/2}$$

Or $\quad q_s = 5.98$ kN/m/hr

Total load, $\quad Q_s = 5.98 \times 50 =$ **299.00 kN/hr**