LECTURE NOTES – X

« HYDROELECTRIC POWER PLANTS »

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Chapter 10

Permissible Velocities in Canals

Conditions of Stable Regime

The maximum permissible velocity in open channels will be limited by the resistance of the bed material to erosion or, in case of lined canals, by that of the lining against wear.

Maximum Permissible Velocities

Some researchers relate permissible bottom velocities to the material of the bed and sides or/and lining, while others suggest values for the permissible mean velocity.

The maximum bottom velocity for erosion is given by *Sternberg* as,

$$V_b = \xi\sqrt{2d} \quad \text{(m/sec)}$$

d = Diameter of particles (m)
$\xi = 4.43$

Erosion velocities for various soil particles are given in the Figure after *W.P.Craeger* and *J.D.Justin*. The range of maximum permissible mean velocities is given for different grain diameters varying from fine clays to gravel of medium fineness (0.001 – 10mm).

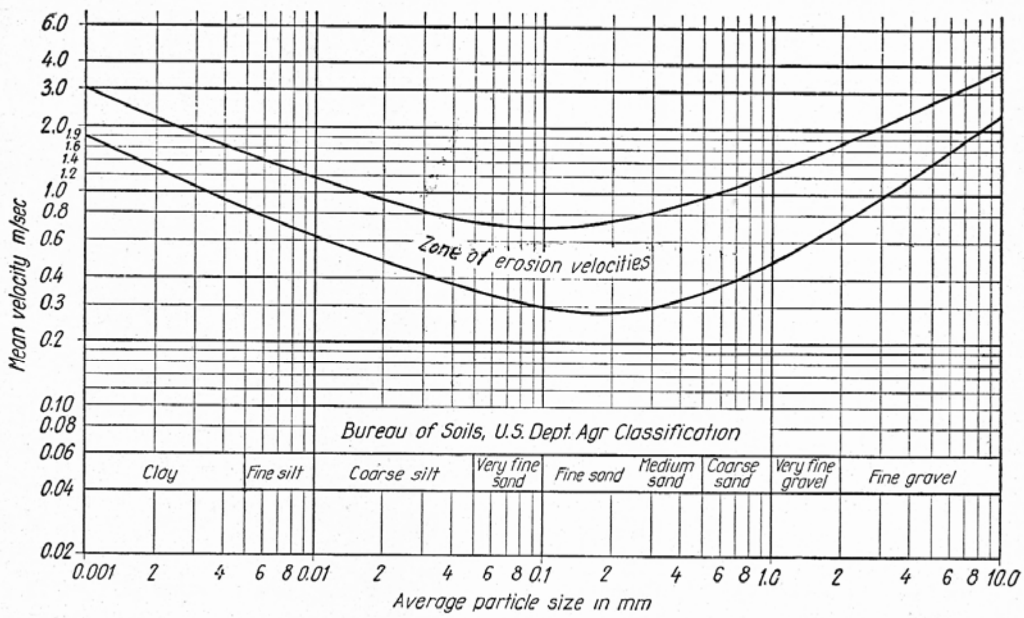

Fig. 1/27. Erosion velocities for various particle sizes, after *W. P. Creager* and *J. D. Justin*.
(Values indicate mean canal velocities)

Abscissa represent average particle sizes in millimeters, while mean velocities on the ordinate axes are in m/sec.

Functions of both particle size and specific weight of the soil are more accurate.

$$V = 22.9 d_m^{4/9} \sqrt{\gamma_1 - 1} \quad \text{(m/sec)}$$

d_m = Effective size (cm)
γ_1 = Specific weight of the material (gr/cm^3)

Maximum permissible mean velocities for loose granular bed material;

TABLE I/27

Maximum permissible mean velocities for loose granular bed material

Material	Diameter of particle d mm	Maximum mean velocity in case of $h = 1$ m v_1 m/sec
Very coarse gravel	200 —150	3.9 —3.3
	150 —100	3.3 —2.7
Coarse gravel	100 — 75	2.7 —2.4
	75 — 50	2.4 —1.9
	50 — 25	1.9 —1.4
	25 — 15	1.4 —1.2
	15 — 10	1.2 —1.0
	10 — 5	1.0 —0.8
Cobble	5 — 2	0.8 —0.6
Coarse sand	2 — 0.5	0.6 —0.4
Fine sand	0.5 — 0.1	0.4 —0.25
Very fine sand (Mo)	0.1 — 0.02	0.25—0.20
Silt	0.02— 0.002	0.2 —0.15

Correction coefficients to formula $v = \alpha v_1$

Depth h	Correction coefficient α
0.3 m	0.80
0.6 m	0.90
1.0 m	1.00
1.5 m	1.10
2.0 m	1.15
2.5 m	1.20
3.0 m	1.25

In case of depths other than 1 m, velocities will be corrected by,

$$V = \alpha V_1$$

Maximum permissible mean velocities for solid rocks and α correction factors,

TABLE II/27

Maximum permissible mean velocities for solid rocks

(Condition: rocks should not be weathered or fissured)

Material	v_1 m/sec
Loose conglomerate, clay loam	2.5—3
Tough conglomerate, porous lime rock, stratified limestone	3—5
Dolomitic sandstone, nonstratified limestone, quartzitic limestone	4.5—7
Marble, granite, syenite, gabbro — coarse	15—25
Same as above — smoothed	27—38
Porphyry, phonolite, andesite, diabas, basalt, quartzite — coarse	24—48
Same as above — smoothed	38—45

Correction coefficients to formula $v = \alpha v_1$

Depth h	Correction coefficient α
0.30 m	0.80
0.50 m	0.90
0.75 m	0.95
1.00 m	1.00
1.50—2.00 m	1.10
2.50—3.00 m	1.20

Maximum permissible velocities for cohesive soils are given in the Table. These values can be corrected for the hydraulic radius, R > 3 m by,

$$\alpha = \left(\frac{R}{3}\right)^{0.1}$$

If the bed is covered by aquatic growths, mean velocities from 0.8 to 1.8 m/sec can be used.

Maximum permissible mean velocities for cohesive soils

Type of soil	v_1 [m/sec]	Note
Slightly clayey sand, very fine sand	0.7—0.8	Tabulated data apply to a hydraulic radius between 1 and 3 m. For $R > 3$ increase by $\left(\frac{R}{3}\right)^{0.1}$
Compacted clayey sand	1.0	
Loose sandy clay or loess	0.7—0.8	
Medium sandy clay	1.0	
Hard sandy clay	1.1—1.2	
Soft clay	0.7	
Ordinary clay	1.2—1.4	
Rolled clay	1.5—1.8	
Silts	0.5—0.6	

Lowest Permissible Velocities

In order to prevent settling of silt suspended in the water, lowest permissible velocities should also be determined. According to *A.Ludin,* no sedimentations is likely to occur if the mean velocity,

V > 0.3 m/sec in case of silty water,

V> 0.3 – 0.5 m/sec in case of water carrying fine sand

Silt-Load Carrying Capacity

E.A. Zamarin's empirical equation gives the silt-load capacity as,

$$G_0 = 700\frac{V}{w_0}\sqrt{\frac{RSV}{w}} \quad (\text{kg/m}^3)$$

G_0 = Silt-load carrying capacity of the water (kg/m^3),
V = Mean flow velocity (m/sec),
R = Hydraulic radius (m),
w = Mean settling velocity (in still water) (mm/sec),
S = Water surface slope
w_0 = w if w > 2 mm/sec, but
w_0 = 2 mm/sec, if $w \leq 2$ mm/sec.

If the silt discharge in the water is smaller than the silt-load carrying capacity of the canal, $G < G_0$, no silting will occur.

The above equation applies only to unlined canals free from aquatic growths, to discharges from 0.2 to 150 m^3/sec and if V > 0.3 m/sec, w < 10 mm/sec and G < 5 kg/m^3.

For approximate values of permissible velocities *M.M. Grishin* suggest the equation,

$$V = AQ^{0.2}$$

With the following values of coefficient A;

w (mm/sec)	< 1.5	1.5 – 3.5	> 3.5
A	0.33	0.44	0.55

Defining d_0 as the decisive size of screen opening on which 25% of the weight of the natural bed material will be hold. The simple relationship between the diameter d_0 (cm) thus defined and the limiting tractive force T_f (kg/m^2) is plotted in the Figure.

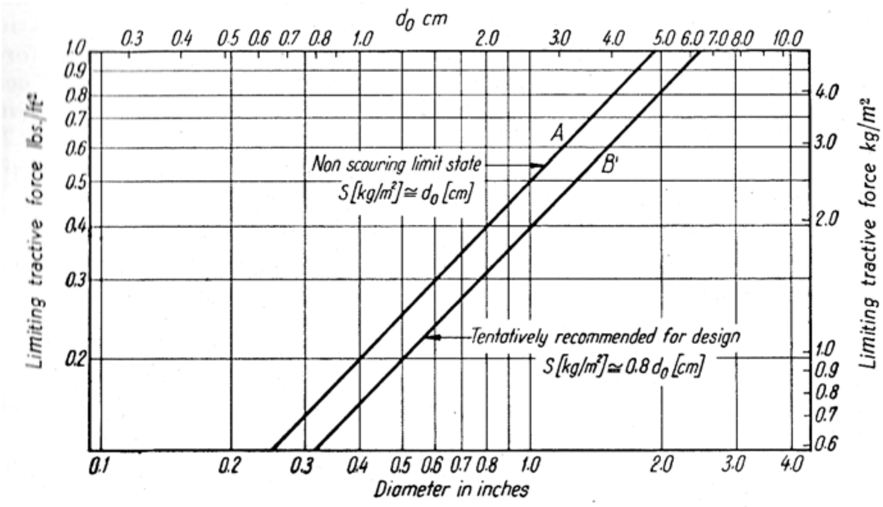

***Fig. 2/27.* Relation between limiting tractive force and decisive diameter of bed material. Results of studies on *San Louis* Valley canals. (After *E. W. Lane* and *E. J. Carlson, Bureau of Reclamation,* USA)**

Curve A represents the limit state of degradation, while curve B should be used for safe design. Considering the two curves more closely, the relationship can be reduced with sufficient accuracy to,

$$T_f\left(kg/m^2\right) \cong d_0(cm)$$

Computing the value of tractive force in (kg/m^2) from the equation,

$$T_f = \gamma hS = 1000hS \quad (\text{kg/m}^2)$$

h = Water depth,
S = Slope of water surface.

The screen opening parameter d_0 in cm concerning to the scaling in the limit state of erosion under the action of the given force. This force T_f is, therefore, referred to as the limiting force for the bed constructed in the material characterized by the parameter d_0. Multiplying the decisive parameter considered to the limiting force by 1.25, the curve B suggested for design purposes is obtained by the safety factor η = 1.25.

$$1.25T_f\left(kg/m^2\right)\cong d_0(cm)$$
$$T_f\left(kg/m^2\right)\cong 0.8d_0(cm)$$

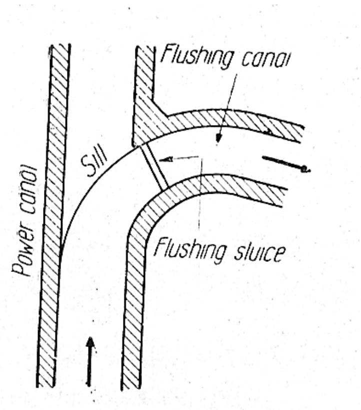

Figure. Flushing of the power canal

Installing a gated spillway of suitable arrangement instead of an overfall weir, a periodical flushing of deposited silt from the power canal and especially from the downstream reaches can be accomplished. In long canals several sluices may be built for this purpose.

A water depth exceeding 1.5 – 2.0 meters and a mean velocity of not less than 0.50 m/sec will be sufficient to prevent the growth of plants.

Example: A power canal with dimensions h = 2.50 m, R = 1.76 m, and S = 0.0001 has a bed load in the original water course as G = 0.34 kg/m^3. The mean settling velocity for a 0.08 mm diameter grain in still water is found to be w = 4.5 mm/sec. The canal is unlined and the average particle size of the bed material is d_m = 2 mm.

Solution: Using Table I/27, for an average particle size d_m = 2 mm, the maximum permissible mean velocity corresponding to a water depth of 1 m, V_1 = 0.6 m/sec. The correction coefficient for h = 2.5 m depth is α = 1.20. The maximum permissible velocity is,

$$V=\alpha V_1=1.20\times 0.60=0.72(m/\sec)$$

G_0 silt-load carrying capacity is,

$$G_0=700\frac{V}{w_0}\sqrt{\frac{RSV}{w}}$$

V = 0.60 m/sec, w = 4.5 cm/sec, w_0 = w (because w > 2 cm/sec), R = 1.76 m, S = 0.0001,

$$G_0=700\times\frac{0.60}{4.5}\times\sqrt{\frac{1.76\times 0.0001\times 0.60}{4.5}}=0.45\,kg/m^3$$

Since,

$$0.72 \text{ m/sec} > 0.60 \text{ m/sec}$$

$$0.34 \text{ kg/m}^3 < 0.45 \text{ kg/m}^3$$

Neither erosion nor silting of the canal is to be feared.