3- Design of Alluvial canals Using Tractive force Method

Canals of erodible material can be designed to prevent the expected scouring. This Method is based on the concept of tractive force. (قوى الجر او السحب)

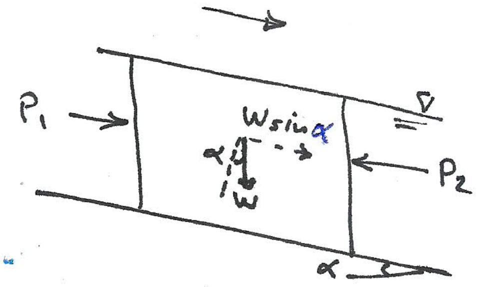
تصميم القنوات الطمويه بأستخدام مبدأ قوى الجر بحيث تمنع حدوث التعريه او التآكل لقعر وجوانب القناة

The scour in a canal occurs when tractive force exerted by flow is adequate to cause movement of bed particle having representative diameter d_s or d_{50}. This method is proposed by Lane also known as the USBR method.

التآكل يحدث عندما تكون قوى الجر المسلطة من قبل الجريان كافية لتحريك جزيئات قاع القناة التي لها d_{50} معين

$$P_1 - P_2 - F + W \sin\alpha = \rho Q (V_2 - V_1)$$

محصلة القوى = التغير بالزخم

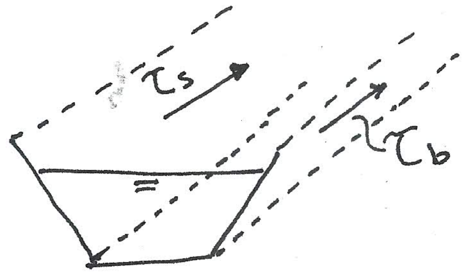


P: pressure V: velocity

F: Resultant force W: weight of soil particle

ρ: density Q: discharge

For uniform flow جريان منتظم



$\therefore P_1 = P_2$, $V_1 = V_2$

اي لا يوجد تغير في السرعة والعمق

$\therefore F = W \sin\alpha$

$F = \tau_b * P * L$ [حيث ان F محصلة القوى تمثل القوة المحركة لجزيئات القاع بأتجاه الجريان]

where τ_b : shear stress at level of bed

τ_s : " " " side slope.

$\therefore \tau_b P L = W \sin\alpha$

$\tau_b P L = (\gamma A L) \tan\alpha$ [since α is small $\therefore \sin\alpha = \tan\alpha$]

$\tau_b P \cancel{L} = \gamma A \cancel{L} S$

$$\boxed{\tau_b = \gamma R S}$$

From some relations, it has been proved that:

$$\frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

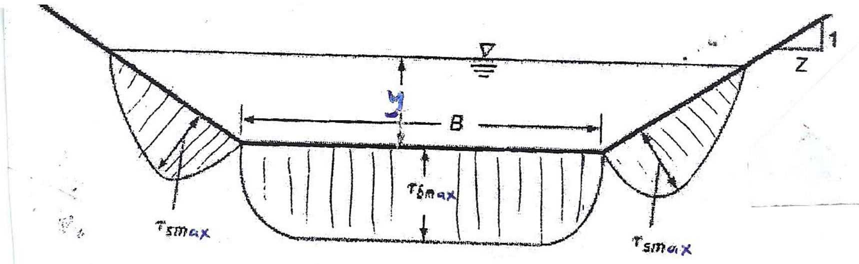


Fig. 1 Variation of boundary shear stress in a trapezoidal channel

where:

$$K = \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$$

K: tractive ratio

θ: side slope $[\tan^{-1}(\frac{1}{z})]$

ϕ: angle of repose زاويه الاحتكاك الداخليه
او زوايه الاستقرار

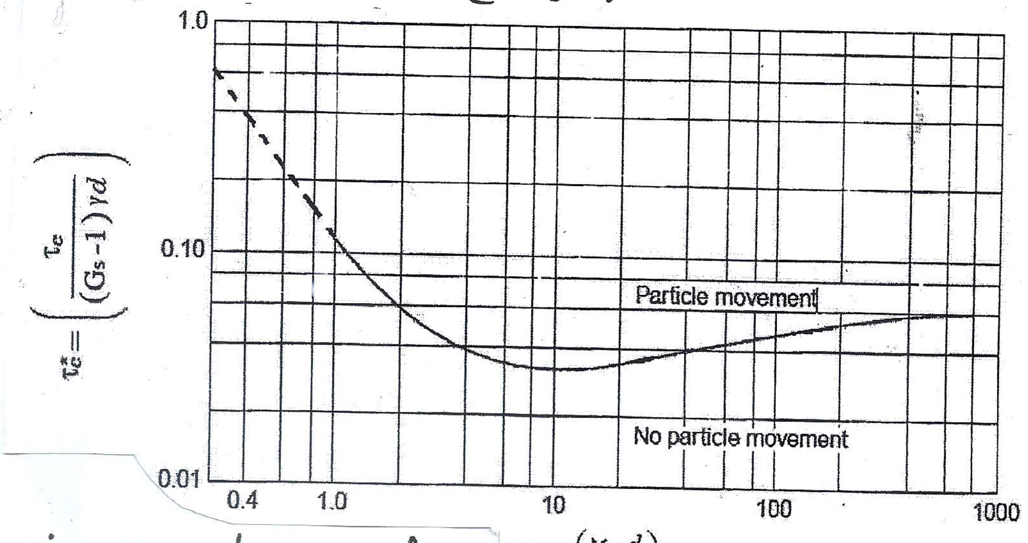
$$\therefore \tau_s = K \, \tau_b$$

In design: τ_b should be less than criticle shear stress τ_c

$$\tau_b < \tau_c$$

let say $\tau_b < 0.9\,\tau_c$

τ_c can be calculated from different approximated methods. τ_c is strongly related to particle size (d). But the more actual value of τ_c, can be obtained from shields diagram shown in fig below (2) also it can be obtained using fig (3) which is adapted form of shields curve for incipient motion [by Yalin & Karahan]



والاخير هو الذي
يستخدم لايجاد
τ_c

Fig (2) shields curve for incipient motion $R_c^* = \left(\frac{V_{*c} d}{\nu}\right)$

where V_*: shear velocity

$V_* = \sqrt{\tau_b/\rho}$

R_c^*: dimensionless Reynolds no. or particle Reynold No.

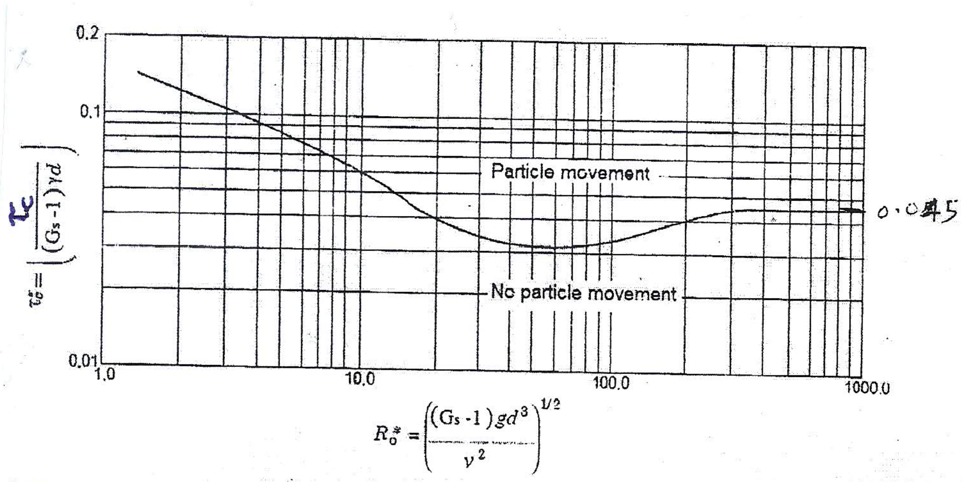


Fig (3) *Yalin and Karahan curve Adapted from Shields curve for incipient motion*

where :

R_o^* : boundary Reynolds No.

How to find τ_c :

① $G_s = \frac{\gamma_s}{\gamma}$

② for given Kinematic viscosity (ν) of water $1 \times 10^{-6} \frac{m^2}{s}$

③ from fig find dimensionless critical shear stress τ_c^*

④ $\tau_c = \tau_c^* (G_s - 1) \gamma \cdot d$

How to design

① For a given d (particle diam.), γ_s (soil density), γ, ν (Kinematic viscosity)

② $\tau_{b_{max}} = 0.9\, \tau_c$

③ $\theta = \tan^{-1} \frac{1}{z}$

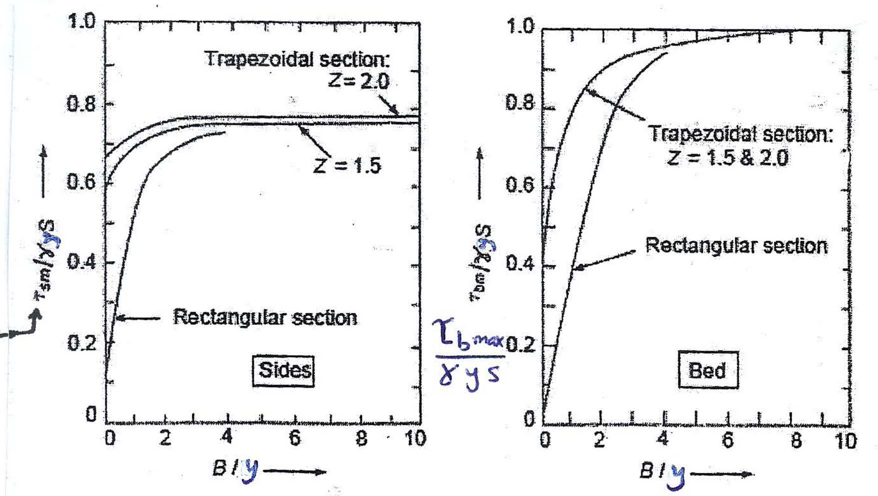
④ ϕ coefficient of friction (angle of repose), Calculate $K = \sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$

⑤ $\tau_{s_{max}} = K\, \tau_{b_{max}}$

⑥ Assume $\frac{B}{y}$ ratio

⑦ from fig below (4) find $\frac{\tau_{s\,max}}{\gamma y s}$ ⇒ find y

$\frac{\tau_{s\,max}}{\gamma y s}$ →



$\frac{\tau_{b\,max}}{\gamma y s}$

Fig. 4 Variation of maximum shear stress on bed and sides of smooth channels

9) Find B

go to step ⑥ ← ⑩ for given Q using Maning equation to check y & B.

EX: Design a trapizoidal canal (Z=2) to carry 25 $\frac{m^3}{s}$. The slope $S = 1\times10^{-4}$. The bed and banks comprise gravel (angle of repose $\phi = 31^\circ$) and the size is 3mm. Use $\nu = 10^{-6}\ m^2/s$ & $n = 0.0148$.

Sol.

$$R_o^* = \left[\frac{(G_s-1)\,g\,d^3}{\nu^2}\right]^{1/2} = \left[\frac{2.65-1\ (9.81)\ (0.003)^3}{1\times10^{-12}}\right]^{1/2}$$

$R_o^* = 661.1$ from fig (3) $\tau_c^* = 0.045$

$\tau_c = 0.045\,(2.65-1)\,9810\,(0.003) = 2.185\ N/m^2$

$\tau_b = 0.9\,\tau_c = 1.97\ N/m^2 = \tau_{b\,max}$

$\theta = \tan^{-1}\frac{1}{2} = 26.56^\circ$

$\tau_b * K = \tau_s \implies \tau_s = 1.97\sqrt{1-\frac{\sin^2 26.56^\circ}{\sin^2 31^\circ}} = 0.977\ N/m^2$

assume $\frac{B}{y} = 10$ since $Q > 10\ m^3/s$ [page 9]

from fig (4)

$\frac{\tau_{s\,max}}{\gamma y s} = 0.78 \implies y = \frac{0.977}{9810 * 1 * 10^{-4} * 0.78} = 1.27\,m$

$B = 10y = 12.7\,m$

$A = By + 2y^2 = 19.355\,m^2$
$P = B + 2\sqrt{5}\,y = 18.38$ } $R = 1.053\,m$

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

$= \frac{1}{0.0148} (19.355)(1.053)^{2/3} (10^{-4})^{0.5}$

$= 13.5\ m^3/s < 25\ m^3/s \Rightarrow$ choose $\frac{B}{y} = 20$

$\frac{B}{y}$	$\frac{\tau_{s\,max}}{\gamma y s}$		B	A	P	R	Q
10	0.78	1.27	12.7	19.355	18.38	1.053	13.5
20	.78	1.27	25.4	35.484	32.08	1.142	26.194

H.W Design the cross sectional of trapezoidal channel carrying discharge of 1.6 m^3/s if $S = 30\ cm/Km$. bed material is silty loam, use $n = 0.025$, $\phi = 36.3^\circ$