الفرقة الثالثة

هيدروليكا

Part (9)

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Equivalent roughness in open channels :

channels with composite roughness :

Einstein

$$\boxed{n = \left[\frac{\sum_{i=1}^{N} P_i\, n_i^{1.5}}{P}\right]^{2/3}}$$

$$= \left[\frac{P_1 n_1^{1.5} + P_2 n_2^{1.5} + \cdots}{P}\right]^{2/3}$$

Pavlovski

$$\boxed{n = \left[\frac{\sum_{i=1}^{N} P_i\, n_i^{2}}{P}\right]^{1/2}}$$

$$= \left[\frac{P_1 n_1^{2} + P_2 n_2^{2} + \cdots}{P}\right]^{1/2}$$

Lotter

$$\boxed{n = \frac{P R^{5/3}}{\sum_{i=1}^{N} \frac{P_i R_i^{5/3}}{n_i}}}$$

$$= \frac{P R^{5/3}}{\frac{P_1 R_1^{5/3}}{n_1} + \frac{P_2 R_2^{5/3}}{n_2} + \cdots}$$

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ملحوظة : عند استخدام معادله Lotter للقطاع المستطيل المتعدد الخشونه

$$R_1 = R_2 = R_3 = \text{-----} = R = \frac{A}{P}$$

- يتم تقسيم القطاع إلى عدة مساحات صغيرة بأخذ خط رأسي عمودي على سطح المياه عند كل كسرة في القاع عندها اختلاف في n

$$P = \sum P_i \qquad R = \cancel{\sum R_i} = \frac{A}{P}$$

$$A = \sum A_i$$

Exams problems

1 – An earthen trapezoidal canal ($n= 0.025$) has $b= 5.0$ m , $y= 1.1$ m and $z= 1.5$. In an economic study to remedy excessive seepage from the canal two proposals (a) To line the sides only and (b) To line the bed only , are considered . If the linning is of smooth concrete ($n= 0.012$), Determine the equivalent roughness in the above two cases using the *Einstein* , *Pavlovski* and *Lotter* methods , then comment on the results .

2 – A rectangular testing channel 60 cm wide and laid on a slope 0.001 . When the channel bed and sides were made smooth by neat cement , the measured normal depth of flow was 42.5 cm for discharge of 253.5 lit/sec. The same channel was then roughened by cemented sand grains , and thus the measured normal depth became 40 cm for discharge 146.3 lit/sec . Determine the discharge for depth 40 cm if the bed was roughened and the sides were kept smooth.

3 – A rectangular channel 4.0 m wide had badly damaged surface and had Manning's $n=0.03$. As a first phase of repair, its bed was lined with concrete ($n= 0.015$). If the depth of flow remains the same at 1.50 m before and after repair , What is the increase of discharge as a result of this repair ?

4 – An open channel carries water with a velocity 0.6 m/sec. If the average shear stress is 1.0 N/m^2 . Determine Chezy's roughness C .

5 – Prove that the friction factor in the Darcy-Weisbach formula is related to Manning's n by:

$$f = \frac{116n^2}{R^{1/3}}$$

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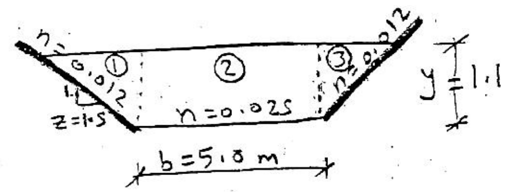
1. ⓐ To line the sides only :



$A = by + zy^2 = 7.32 \ m^2$

$P = b + 2y\sqrt{z^2+1} = 8.97 \ m$

$R = \frac{A}{P} = 0.816 \ m$

Zone ① ≡ Zone ③ :

$A1 = \frac{1}{2} \times 1.1 \times (1.5 \times 1.1) = 0.91 \ m^2$

$P_1 = \sqrt{1.1^2 + 1.65^2} = 1.98 \ m$

$R_1 = 0.46 \ m$

Zone ② :

$A_2 = 5.0 \times 1.1 = 5.5 \ m^2$

$P_2 = 5.0 \ m$

$R_2 = 1.1 \ m$

→ Einstein $\quad n_{eq} = \left[\frac{\sum P_i n_i^{1.5}}{P} \right]^{2/3}$

$$= \left[\frac{2 \times 1.98 \times 0.012^{1.5} + 5.0 \times 0.025^{1.5}}{8.97} \right]^{2/3} = \underline{\underline{0.0198}}$$

→ Pavlovski $\quad n_{eq} = \left[\frac{\sum P_i n_i^2}{P} \right]^{1/2}$

$$= \left[\frac{2 \times 1.98 \times 0.012^2 + 5.0 \times 0.025^2}{8.97} \right]^{1/2} = \underline{\underline{0.02}}$$

→ Lotter $\quad n_{eq} = \frac{P R^{5/3}}{\sum \frac{P_i R_i^{5/3}}{n_i}}$

$$= \frac{8.97 \times 0.816^{5/3}}{2 \times \frac{1.98 \times 0.46^{5/3}}{0.012} + \frac{5.0 \times 1.1^{5/3}}{0.025}} = \underline{\underline{0.0197}}$$

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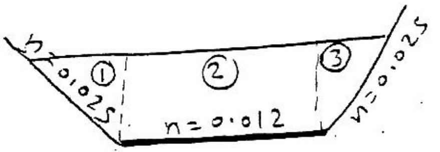
(b) To line the bed only



→ Einstein

$$n_{eq} = \left[\frac{2 \times 1.98 \times 0.025^{1.5} + 5.0 \times 0.012^{1.5}}{8.97} \right]^{2/3} = 0.0183$$

→ Pavlovski

$$n_{eq} = \left[\frac{2 \times 1.98 \times 0.025^{2} + 5.0 \times 0.012^{2}}{8.97} \right]^{1/2} = 0.0189$$

→ Lotter

$$n_{eq} = \frac{8.97 \times 0.816^{5/3}}{2 \times \frac{1.98 \times 0.46^{5/3}}{0.025} + \frac{5.0 \times 1.1^{5/3}}{0.012}} = 0.012$$

$$Q = \frac{A}{n_{eq}} R^{2/3} S_o^{1/2}$$

$$Q \propto \frac{1}{n_{eq}}$$

كلما قلت قيمة n_{eq} كلما كان أفضل حيث
أن كمية التصرف في القطاع ستزيد
ولذلك فإن حالة تبطين القاع أفضل هيدروليكيا من تبطين الجوانب

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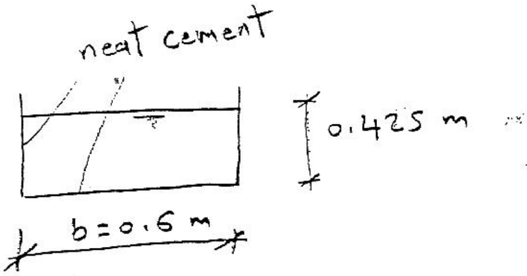
[2] $S = 0.001$

$Q_{\text{neat cement}} = 253.5 \text{ lit/sec}$

$= 0.2535 \text{ m}^3/\text{sec}$



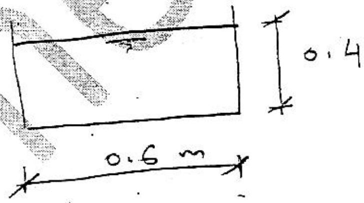
$\rightarrow \quad Q = \frac{A}{n} R^{2/3} S^{1/2}$

$$0.2535 = \frac{0.6 \times 0.425}{n_{\text{neat cement}}} \left(\frac{0.6 \times 0.425}{0.6 + 2 \times 0.425}\right)^{2/3} \sqrt{0.001}$$

$\therefore \; n_{\text{neat cement}} = \underline{\underline{0.01}} = n_1 = n_3$

$\rightarrow \quad Q_{\text{cemented sand grains}} = 146.3 \text{ lit/sec}$

$= 0.1463 \text{ m}^3/\text{sec}$



$$0.1463 = \frac{0.6 \times 0.4}{n_{\text{cemented sand grains}}} \left(\frac{0.6 \times 0.4}{0.6 + 2 \times 0.4}\right)^{2/3} \sqrt{0.001}$$

$\therefore \; n_{\text{cemented sand grains}} = \underline{\underline{0.016}} = n_2$

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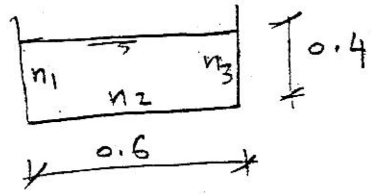
$\rightarrow \quad Q = ??$



$P_1 = P_3 = 0.4 \text{ m}$

$P_2 = 0.6$

$R_1 = R_2 = R_3 = R = \frac{A}{P}$

$= \frac{0.24}{1.4} = 0.17 \text{ m}$

$A = 0.6 \times 0.4 = 0.24 \text{ m}^2$

$P = 0.6 + 2 \times 0.4 = 1.4 \text{ m}$

$\Rightarrow$ Einstein $\quad n_{eq} = \left[\frac{\sum P_i n_i^{1.5}}{P}\right]^{2/3}$

$$= \left[\frac{2 \times 0.4 \times 0.01^{1.5} + 0.6 \times 0.016^{1.5}}{1.4}\right]^{2/3} = 0.0127$$

$\Rightarrow$ Pavlovski $n_{eq} = \left[\frac{\sum P_i n_i^2}{P} \right]^{1/2}$

$$= \left[\frac{2 \times 0.4 \times 0.01^2 + 0.6 \times 0.016^2}{1.4} \right]^{1/2} = 0.0129$$

$\Rightarrow$ Lotter $n_{eq} = \frac{P R^{5/3}}{\sum \frac{P_i R_i^{5/3}}{n_i}}$

$$= \frac{1.4 \times 0.17^{5/3}}{2 \times \frac{0.4 \times 0.17^{5/3}}{0.01} + \frac{0.6 \times 0.17^{5/3}}{0.016}} = 0.0119$$

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

$$= \frac{0.24}{n_{eq}} (0.17)^{2/3} \sqrt{0.001}$$

$\Rightarrow$ Einstein : $Q = 0.183 \ m^3/sec$

$\Rightarrow$ Pavlovskey: $Q = 0.181 \ m^3/sec$

$\Rightarrow$ Lotter : $Q = 0.196 \ m^3/sec$

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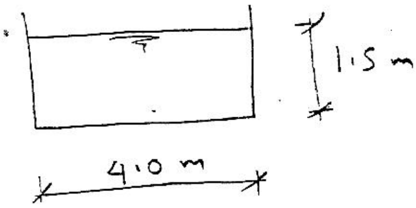

Before Repair :

$$n_{bed} = n_{sides} = 0.03$$

After repair :

$$n_{bed} = 0.015$$

$$n_{sides} = 0.03$$

$$P = 4 + 2 \times 1.5 = 7 \text{ m}$$

$$A = 4 \times 1.5 = 6 \text{ m}^2$$

$$P_1 = P_3 = 1.5 \text{ m}$$

$$P_2 = 4.0 \text{ m}$$

$$R_1 = R_2 = R_3 = R = \frac{A}{P} = \frac{4 \times 1.5}{4 + 2 \times 1.5} = 0.86 \text{ m}$$

→ **Before repair :**

$$Q_{before} = \frac{A}{0.03} R^{2/3} S^{1/2}$$

→ **After repair :**

- Use Pavlovski method

$$n_{eq} = \left[\frac{\sum P_i \cdot n_i^2}{P}\right]^{1/2}$$

$$= \left[\frac{2 \times 1.5 \times 0.03^2 + 4 \times 0.015^2}{7}\right]^{1/2} = 0.0227$$

$$Q_{after} = \frac{A}{0.0227} R^{2/3} S^{1/2}$$

$$\frac{Q_{after}}{Q_{before}} = \frac{0.03}{0.0227} = 1.32$$

As a result of repair, the discharge increased by **32 %**

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- Use Einstein method

$$n = \left[\frac{\sum P_i n_i^{1.5}}{P} \right]^{2/3}$$

$$= \left[\frac{2 \times 1.5 \times 0.03^{1.5} + 4 \times 0.015^{1.5}}{7} \right]^{2/3} = 0.0221$$

$$\frac{Q_{after}}{Q_{before}} = \frac{0.03}{0.0221} = 1.36$$

$\therefore$ the discharge increased by 36 %

- Use Lotter method

$$R_1 = R_2 = R_3 = R = \frac{A}{P} = 0.86\,m$$

$$n = \frac{P R^{5/3}}{\sum \frac{P_i R_i^{5/3}}{n_i}}$$

$$= \frac{7 * (0.86)^{5/3}}{2 * \frac{1.5 \times 0.86^{5/3}}{0.03} + \frac{4 \times 0.86^{5/3}}{0.015}} = 0.0191$$

$$\frac{Q_{after}}{Q_{befor}} = \frac{0.03}{0.0191} = 1.57$$

$\therefore$ the discharge increased by 57 %

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$\boxed{4}$ $V = 0.6\ m/sec$ $C = ??$

$\tau_o = 1.0\ N/m^2$

Sol

$V = C\sqrt{R S_o}$ — ①

$\tau_o = \gamma R S_o$ بأخذ الجزر التربيعي للطرفين

$\sqrt{\frac{\tau_o}{\gamma}} = \sqrt{R S_o}$ — ②

substitute from ② in ① we get

$V = C\sqrt{\frac{\tau_o}{\gamma}}$

$0.6 = C\sqrt{\frac{1.0}{9810}} \Rightarrow$ Chezy's $C = \underline{\underline{59.43}}$

—— * —— * ——

$\boxed{5}$ Prove: $f = \frac{116\ n^2}{R^{1/3}}$

$C = \frac{1.49}{n} R^{1/6}$ English units

$C = \sqrt{\frac{8g}{f}}$ substitute $g = 32.2$ ft/sec for English units

$\frac{1.49}{n} R^{1/6} = \sqrt{\frac{8 \times 32.2}{f}}$ بتربيع الطرفين

$\frac{(1.49)^2}{n^2} R^{1/3} = \frac{257.6}{f}$

$\therefore f = \frac{116\ n^2}{R^{1/3}}$ #

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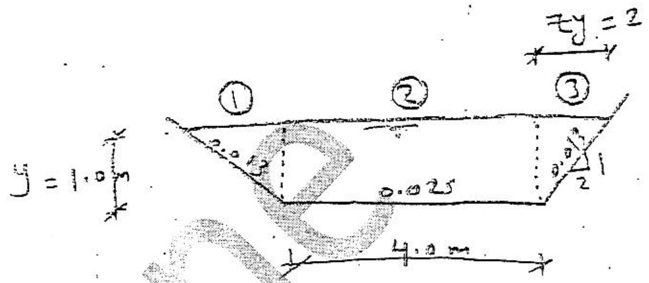
Ex: A trapezoidal channel with bed slope of 0.005, bed width 4.0 m and side slopes 2:1 has a gravel bed (n = 0.025) and concrete sides (n = 0.013) Calculate the uniform flow discharge for a depth of 1.0 m Using:

(i) Einstein (ii) Pavlovski (iii) Lotter



Zone ① = Zone ③

$P_1 = \sqrt{1^2+2^2} = \sqrt{5} = 2.236$ m

$A_1 = \frac{1}{2} \times 2 \times 1 = 1$ m^2

$R_1 = \frac{A_1}{P_1} = \frac{1}{\sqrt{5}} = 0.4472$ m

Zone ②

$P_2 = 4$ m

$A_2 = 4 \times 1 = 4$ m^2

$R_2 = \frac{A_2}{P_2} =$

$A = 6$ m^2

$P = 8.472$ m

$R = \frac{A}{P} = 0.708$ m

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Einstein $n = \left[\frac{\sum P_i n_i^{1.5}}{P}\right]^{2/3}$

$$= \left[\frac{2 \times 2.236 \times 0.013^{1.5} + 4 \times 0.025^{1.5}}{8.472}\right]^{2/3} = \underline{0.0191}$$

Pavlovski $n = \left[\frac{\sum P_i n_i^2}{P}\right]^{1/2} = \underline{0.0196}$

Lotter $n = \frac{P R^{5/3}}{\sum \frac{P_i R_i^{5/3}}{n_i}} = \frac{8.472 \times 0.708^{5/3}}{\frac{2 \times 2.236 \times 0.447^{5/3}}{0.013} + \frac{4 \times 1^{5/3}}{0.025}} = \underline{0.0191}$

$$Q = \frac{A}{n} R^{2/3} S_o^{1/2} = \frac{6}{n} (0.708)^{2/3} \sqrt{0.005}$$

Einstein $Q = 17.645$ m^3/sec

Pavlovskey $Q = 17.195$ m^3/sec

Lotter $Q = 17.645$ m^3/sec