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CIVIL ENGINEERING

IRRIGATION ENGINEERING

Text Book & Work Book :
Theory with worked out Examples and Practice Questions

7 Irrigation Engineering

(Solutions for Text Book Practice Questions)

01. Basics of water resources Engineering

Objective Practice Solutions

02. Ans: (a)

Sol: Q = 50 *l*it/sec ⇒ 5×10^{-3} m^3/s

$$f = 5\,cm/hr \Rightarrow \frac{5\times10^{-2}}{3600}\,m^2/s$$

$$A_{max} = \frac{Q}{f} = \frac{5\times10^{-3}}{5\times10^{-2}}\times3600$$

$= 3600\ m^2$

1 ha = 10000 m

1 ha = 10^4 m

In hectares = 3600 × 10^{-4} hectares

= 0.36 ha

Conventional Practice Solutions

01.

Sol: Time required to irrigate

A = 0.04 ha = 400 m^2

$$f = 5\ cm/hr = \frac{5\times10^{-2}}{3600}\,m/s$$

y = 10 cm = 10^{-1} m

Q = 0.02 cumec = 2×10^{-2} m^3/s

$$t = \frac{y}{f}\log_e\left(\frac{Q}{Q-fA}\right)$$

$$= \frac{10^{-1}}{5\times10^{-2}}3600\log_e\left(\frac{2\times10^{-2}}{2\times10^{-2}-\frac{5\times10^{-2}}{3600}(400)}\right)$$

$$= 7.2\times10^3\log_e\left(\frac{72}{52}\right)$$

= 2343 sec = 39 min

(b) $$A_{max} = \frac{Q}{f} = \frac{2\times10^{-2}}{5\times10^{-2}}\times3600$$

= 1440 m^2

02. Soil, water and plant

Objective Practice Solutions

01. Ans: (b)

Sol:

Evapo-transpiration (E.T) = $c_u \Leftrightarrow d_w$

$$f = \frac{d_w}{c_u}$$

$d_w = c_u$

$d_w = Sd[FC - OMC]$

= 1.3×70 [0.28–0.16]

= 10.92 cm

Note

In this problem time frequency is taken as 1 day ⇒ f = 1

02. Ans: (b)

Sol: Leaching is not separately mentioned in this case

$\Rightarrow$ CIR = NIR

$$GIR = \frac{NIR}{\eta_i} = \frac{NIR}{\eta_a.\eta_c} = \frac{14.9}{(0.8)(0.7)} = 26.6\,cm$$

03. Ans: (c)

Sol: Available Moisture (A.M) $\Rightarrow$ y in depth

$$S = \frac{12.75}{9.81} \Rightarrow \frac{\gamma_{soil}}{\gamma_w}(Soil)$$

= 1.3

y = Sd[FC –pwp]

= 1.3×80 [35–0.2]

y = 15.6 cm

Conventional Practice Solutions

01.

Sol: FC = 35% OMC = 20%

d = 0.8 m PWP = 10%

$y_{supplied}$ = 250 mm

$y_{required}$ to be supplied for healthy growth

= sd[FC – OMC]

$$= 1.6(800)\left[\frac{35-20}{100}\right] = 192 \text{ mm}$$

% water wasted (unnecessarily supplied)

$$= \frac{250-192}{250} \times 100 = 23.2\%$$

02.

Sol: FC = 27%, d = 80 cm, OMC = 18%

PWP = 13% , $s = \frac{1.5}{1} = 1.5$

i) y = sd [FC –PWP]

$$= 1.5(80)\left(\frac{27-13}{100}\right) = 16.8 \text{ cm}$$

ii) d_w= sd [FC – OMC]

$$= 1.5(80)\left(\frac{27-18}{100}\right) = 10.8 \text{ cm}$$

03. Water Requirement of Crops

Conceptual Solutions

08. Ans: (d)

Sol: Δ_{Kor} = 15.12 cm

D = ?

B_{Kor} = 4 weeks

$$\Delta = 846\frac{B}{D}$$

$$15.12 = \frac{846(28)}{D}$$

(B in weeks → days ⇒ 4× 7 = 28 days)

= 1600 ha/cumec

`

17. Ans: (c)

Sol: **Volume$_{canal}$** = Area × y_{canal}

$$= 10\times10^4 \times \frac{y_{field}}{\eta}$$

$$= 10\times10^4 \times \frac{10\times10^{-2}}{0.9}$$

= 11, 111.11 m^3

($\therefore$ 1m^3 = 1000 lit = 1 KL)

= 11,111 kL

19. Ans: (d)

Sol: The annual intensity of irrigation for this state

$$= \left(\frac{4.5}{5} \times 90\right) + \left(\frac{2.5}{5} \times 80\right) = 121\%$$

Objective Practice Solutions

02. Ans: (c)

Sol: $$\frac{50}{100} = \frac{\text{Area to be irrigated}}{8000 - 8000 \times \frac{30}{100}}$$

0.05 × 5600 = Area to be irrigated

Area to be irrigated = 2800 hect

03. Ans: (c)

Sol: Base period = 90 days

$$D = 8.64 \frac{B}{\Delta}$$

$$= 8.64 \times \frac{90}{(105-15)}$$

$= 8.64 \times 1$ ha/ cm^3

$= 864$ ha / m^3

04. Ans: (d)

Sol: $\eta_a = 0.8$, $\eta_c = 0.7$

Net irrigation requirement, NIR = 14.9

$$FIR = \frac{NIR}{\eta_a} = \frac{14.9}{0.8} = 18.625\,\text{cm}$$

$$\therefore\ GIR = \frac{FIR}{\eta_c} = \frac{18.625}{0.7} = 26.607\,\text{cm}$$

Conventional Practice Solutions

01.

Sol: Watering interval

i.e frequency of irrigation = ?

FC = 30%, PWP = 11%, $\rho_{soil} = 1300$ kg/m^3

d = 700 mm , $C_u = 12$ mm/day

$$s = \frac{1300}{1000} = 1.3$$

RAM = 75% AM, because mc should not fall below 25% of water holding capacity

$d_w = 0.75$ y

= 0.75 sd (FC – PWP)

$$f = \frac{d_w}{C_u} = \frac{0.75(1.3)(700)}{12}\left[\frac{30-11}{100}\right]$$

= 10.8 days

03.

Sol: Depth and frequency of irrigation = ?

d = 90 cm

FC = 22%, PWP = 12%, s = 1.5

$d_w = 50\%$ y, $C_u = 6$ mm/day

$d_w = 50\%$ y = 0.5 y = 0.5 sd [FC– PWP]

$$= 0.5 \times 1.5 \times (90)\left[\frac{22-12}{100}\right]$$

= 6.75 cm = 67.5 mm

$$f = \frac{d_w}{C_u} = \frac{67.5}{6} = 11.25\ \text{days}$$

04.

Sol: FC = 23%, PWP = 10%

d = 65 cm, OMC = 10% , $\eta_a = 0.7$

$\gamma_d = 1.5$gm/cc

$$s = \frac{\gamma_d}{\gamma_w} = \frac{1.5}{1} = 1.5$$

Storage capacity of soil,

$$y = sd\,[FC - PWP] = 1.5 \times 65\left(\frac{23-10}{100}\right)$$

= 12.7 cm

$$y_{field} = \frac{y_{plant}}{\eta_a} = \frac{sd[FC - OMC]}{\eta_a}$$

$$= \frac{1.5(65)}{0.7}\frac{(23-10)}{100}$$

= 18.1 cm

05.

Sol: $Q_c = 150$ *l*ps   t = 8 hours

$Q_f = 110$ *l*ps   A = 2.2 ha

Runoff loss in field = 445 m^3

$y_f = 1.5$ m (entry), $y_p = 1.1$ m (exit)

d = 1.5 m

y = 200 mm per meter depth

= 200 × 1.5 = 300 mm

Irrigation was started at a moisture extraction level of 50%

$d_w = 0.5\,y = 0.5\,(300) = 150$ mm

$$\eta_c = \frac{Q_f}{Q_c} \times 100 = \frac{110}{150} \times 100 = 73.33\%$$

$\forall_f = Q_f t = 110 \times 10^{-3} \times 8 \times 3600 = 3168\ m^3$

Runoff loss = 445 m^3

$\forall_{plant} = \forall_f - \text{losses} = 3168 - 445$

= 2723

$$\eta_a = \frac{\forall_{plant}}{\forall_{field}} \times 100$$

$$= \frac{2723}{3168} \times 100 = 85.95\% = 86\%$$

For η_d:

$$y_m = \frac{y_1 + y_2}{2} = \frac{1.5 + 1.1}{2} = 1.3\text{m}$$

$$y_d = \frac{0.2 + 0.2}{2} = 0.2\text{m}$$

$$\eta_d = \left(1 - \frac{y_d}{y_m}\right)100$$

$$= \left(1 - \frac{0.2}{1.3}\right)100$$

$$= \frac{1.1}{1.3} \times 100$$

= 84.6%

06.

Sol: CCA = 2600 ha

Sugarcane I = 20%

$$\Rightarrow A = \frac{20}{100}(2600) = 520\ \text{ha}$$

Rice I = 40%

$$\Rightarrow A = \frac{40}{100}(2600) = 1040\ \text{ha}$$

Duties:

750 ha/cumec for Sugarcane

1800 ha/cumec for Rice

$Q_{average} = Q_{sc} + Q_{rice}$

$= \frac{A_1}{D_1} + \frac{A_2}{D_2}$

$= \frac{520}{750} + \frac{1040}{1800}$

= 0.693 + 0.58

= 1.273

$Q_{Required} = 1.2\ (Q_{av})$

$= 1.2 \times 1.273$

= 1.525 cumec

07.

Sol: The canal with higher duty is more efficiency

Left canal:

$$D = \frac{A}{Q} = \frac{80\%(20{,}000)}{20} = 800 \text{ ha/cumec}$$

Right canal:

$$D = \frac{A}{Q} = \frac{\frac{50}{100}(12000)}{8}$$

= 750 ha/cumec

$\therefore$ **Left canal is more efficient**

08.

Sol: GCA = 1000 ha

I = 70%, CCA = 700 ha

B = 15 days, $C_u = 500$ mm, $P_e = 120$ mm

CIR = $C_u - P_e$ = 380 mm = Δ = 38 cm

$\Delta = 8.64$ B/D

$= 864$ B/D $\Rightarrow D = \frac{864B}{\Delta}$

$$D_{field} = \frac{864(15)}{38} = 341 \text{ ha/cumec}$$

$\eta_c = 0.8$

$$\frac{D_{canal}}{D_{field}} = \eta_c$$

$D_{canal} = 0.8\ (341) = 273$ ha/cumec

$$Q = \frac{A}{D_{canal}} = \frac{700}{273} = 2.564 \text{ cumec}$$

09.

Sol: $C_u = kf$

$$= \frac{KP(1.8t + 32)}{40}$$

$$C_u \text{ for Nov} = \frac{0.75(7.91)[1.8(19) + 32]}{40}$$

= 8.924 cm

$$C_u \text{ for Dec} = \frac{0.75(7.15)[1.8(16) + 32]}{40}$$

= 8.151 cm

$$C_u \text{ for Jan} = \frac{0.75(7.30)[1.8(12.5) + 32]}{40}$$

= 7.460 cm

$$C_u \text{ for Feb} = \frac{0.75(7.03)[1.8(13) + 32]}{40}$$

= 7.302 cm

C_u for season = ΣC_u

$= 31.837$ cm

Rainfall of season = 1.2 + 0.8 = 2 cm

$CIR = C_u - P_e$

$= 31.837 - 2 = 29.837$ cm

$\eta_a = 0.7$

$$FIR = \frac{CIR}{\eta_a}$$

$$= \frac{29.837}{0.7} = 42.624 \text{ cm}$$

10.

Sol: y values

2.0 , 1.9, 1.8, 1.6, 1.5 m

$$y_m = \frac{\Sigma y_i}{n} = \frac{8.8}{5} = 1.76 \text{ m}$$

$$y_d = \Sigma y_i = \frac{|2-1.76| + |1.9-1.76| + |1.8-1.76| + |1.6-1.76| + |1.5-1.76|}{5}$$

$$= \frac{0.24 + 0.14 + 0.04 + 0.16 + 0.26}{5}$$

$$= \frac{0.84}{5} = 0.168\text{m}$$

$$\eta_d = \left[1 - \frac{y_d}{y_m}\right]100 = \left[1 - \frac{0.168}{1.76}\right]100 = 90.45\ \%$$

12.

Sol: FC = 38%, $C_u = 15$ mm/day

PWP = 10%, $\eta_i = 0.6$,

n = 45%

$$\Rightarrow e = \frac{0.45}{0.55} = 0.8$$

d = 1 m

$d_w = 0.5y$ (given)

$= 0.5$ sd [FC– PWP]

$$f = \frac{d_w}{C_u} = \frac{0.5sd[FC - PWP]}{C_u}$$

To calculate specific gravity(s):

$$e \times D_s = FC \times G_s \quad \& \quad \gamma_d = \frac{G_s \gamma_w}{1+e}$$

Where e = void ratio

D_s = Degree of saturation

FC = Field capacity

G_s = Specific gravity for saturated soil

$$S = \frac{\gamma_d}{\gamma_w} = \frac{G_s}{1+e}$$

$$= \frac{eD_s}{(FC)(1+e)} = \frac{0.8(1)}{0.38(18)}$$

$= 1.17$

$$f = \frac{d_w}{C_u}$$

$$= \frac{0.5sd[FC - PWP]}{C_u}$$

$$= \frac{0.5(1.17)(100)[0.38 - 0.1]}{1.5}$$

= 10.92 days

= 11 days

04. Quality of irrigation water

Conceptual Solutions

05. Ans: (c)

Sol: Na^{+} = 345ppm

Ca^{++} = 60 ppm

Mg^{++} = 16 ppm

Converting them into milli equivalent / litre

Milli equivalent / wire

$$= \frac{\text{concentration in ppm}}{\text{equivalent weight of element}}$$

$$Na^{+} = \frac{345}{23} = 15$$

$$Ca^{++} = \frac{60}{30} = 2$$

$$Mg^{++} = \frac{18}{12} = \frac{3}{2} = 1.5$$

Sodium absorption ratio (SAR)

$$= \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = \frac{15}{\sqrt{\frac{2+1.5}{2}}} = 11.33$$

10. Ans: (a)

Sol: If electro conductivity < 4000 ⇒ black alkali soil

If electro conductivity > 4000 ⇒ white alkali soil

05. Design of Lined Canals

Conceptual Solutions

03. Ans: (a)

Sol: Given channel is triangular lined channel

$$\Rightarrow \text{ Area} = y^2(\theta + \cot\theta)$$

Here $\tan\theta = \frac{1}{1.5} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{1.5}\right) = 33.69$

$$\theta = 33.69 \times \frac{\pi}{180} = 0.588$$

$\cot\theta = 1.5$

Area = $(2.5)^2$ (0.58 + 1.5)

Area = 13

We know = Q = AV

26 = 13 × V

V = 2m/s

Considering F.O.S as 1.1

⇒ V = 2 × 1.1 = 2.2

Objective Practice Solutions

01. Ans: (c)

Sol: y = 4 m

R = ?

A = y^2 (θ +cotθ)

P = 2y (θ + cotθ)

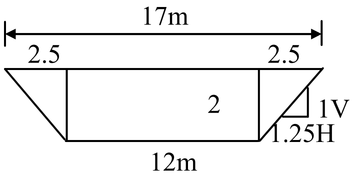
$$R = \frac{A}{P} = \frac{y^3(\theta + \cot\theta)}{2y(\theta + \cot\theta)}$$

y = 4 m

$$R = \frac{4}{2} = 2m$$

02. Ans: (c)

Sol:



FSD⇒ Full supply depth

$$A = \frac{(12+17)\times 2}{2} = 29\,m^2$$

$$P = 12 + 2\left(\sqrt{2.5^2 + 2^2}\right)$$
$$= 18.40$$

$$R = \frac{A}{P} = \frac{29}{18.40} = 1.576$$

Conventional Practice Solutions

01.

Sol: Lined canal

Q = 30 cumec

$$S = \frac{22.5cm}{km}$$
$$= \frac{22.5}{100000}$$

N = 0.012

$$\cot\theta = \frac{H}{V} = \frac{1.5}{1}$$

Since Q = 30 < 100 cumec, we must provide triangular lined canal with rounded bottom.

$\cot\theta = 1.5$

$$\theta = \cot^{-1}(1.5) = \tan^{-1}\left(\frac{2}{3}\right) = 0.588$$

$\theta + \cot\theta = 2.088$

$A = y^2(\theta + \cot\theta) = 2.088\,y^2$

$P = 2y(\theta + \cot\theta) = 2(2.088)y$

$$R = \frac{A}{P} = \frac{y}{2}$$

$$Q = AV = A\,\frac{1}{N}R^{2/3}S^{1/2}$$

$$30 = \left(2.088y^2\right)\frac{1}{0.012}\left(\frac{y}{2}\right)^{2/3}\left(\frac{22.5}{10^5}\right)^{1/2}$$

$$y^{8/3} = \frac{30(0.012)\left(2^{2/3}\right)}{2.088\times 225^{1/2}}\left(10^6\right)^{1/2}$$

$\Rightarrow y = 2.9712$ m

$y = 3$ m

04.

Sol: $S = \frac{1}{2000}$

$Q = 30\ m^3/s \Rightarrow$ (Triangular section with rounded bottom)

N = 0.012

$$\cot\theta = \frac{2H}{1V} = 2$$

Q = 30 cumec

$\theta = \cot^{-1}(2) = 0.464$

$\theta + \cot\theta = 2.464$

$A = y^2(\theta + \cot\theta) = 2.464\,y^2$

$P = 2y(\theta + \cot\theta) = 2y(2.464)$

$$R = \frac{A}{P} = \frac{y}{2}$$

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

$$30 = 2.464y^2\ \frac{1}{0.012}\left(\frac{y}{2}\right)^{2/3}\left(\frac{1}{2000}\right)^{1/2}$$

$$y^{8/3} = \frac{30(0.012)2^{2/3}(2000)^{1/2}}{2.464}$$

$\Rightarrow y = 2.404$ m

$y = 2.4$ m

06.

Sol: $Q = 20\ m^3/s$

Trapezoidal lined canal

$$\cot\theta = \frac{1.5H}{1V} = \frac{3}{2}$$

$$\theta = \cot^{-1}\left(\frac{3}{2}\right) = 0.588$$

$\theta + \cot\theta = 2.088$

$N = 0.015$

$V = 1$ m/s

For minimum amount of lining, wetted perimeter should be minimum

$$A = By + y^2(\theta + \cot\theta) = \frac{\theta}{V} = 20$$

$$20 = By + 2.088\ y^2$$

$$B = \frac{20 - 2.088y^2}{y}$$

$$P = B + 2y\ (\theta + \cot\theta)$$

$$P = \frac{20}{y} - 2.088y + 4.176y$$

$$P = \frac{20}{y} + 2.088y$$

$$\frac{dP}{dy} = 0 \Rightarrow \frac{-20}{y^2} + 2.088 = 0$$

$$20 = 2.088\ y^2$$

$\Rightarrow y = 1.76$ m

$$P = \frac{20}{1.76} + 2.088(1.76) = 15m$$

$$V = \frac{1}{N}R^{2/3}S^{1/2}$$

$$1 = \frac{1}{0.015}\left(\frac{20}{15}\right)^{2/3} S^{1/2}$$

$$\Rightarrow S = \frac{1}{6520}$$

07.

Sol: Trapezoidal cross section

$Q = 250\ m^3/s$, $S = \frac{1}{6000}$

$\cot\theta = \frac{1.5}{1}$, $\theta = \cot^{-1}(1.5) = 0.588$

$\theta + \cot\theta = 2.088$

$y = 3$ m

$N = 0.015$

$A = By + y^2(\theta + \cot\theta) = 3B + 9(2.088)$

$= 3B + 18.792$

$P = B + 2y(\theta + \cot\theta) = B + 6(2.088)$

$= B + 12.528$

$$R = \frac{A}{P} = \frac{3B + 18.792}{B + 12.528}$$

$$Q = AV$$

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

$$250 = (2B + 18.792)\frac{1}{0.015}\left(\frac{3B + 18.792}{B + 12.528}\right)^{2/3}\left(\frac{1}{6000}\right)^{1/2}$$

$$\Rightarrow B = 44 \text{ m}$$

$$y = 3 \text{ m}$$

08. Refer solution of question 1

06. Design of unlined canals in alluvial soils

Conceptual Solutions

02. Ans: (b)

Sol: $V = mV_0$

$= 0.55 \times 0.90 \times 1 = 0.495$

03. Ans: (c)

Sol: $$\tau_c^1 = \tau_c\sqrt{\frac{1 - \sin^2\theta}{\sin^2\phi}}$$

$$\cot\theta = 1.5 = \frac{3}{2}$$

$$\sin\theta = \frac{2}{\sqrt{13}}$$

$$\phi = 37°$$

$$\sin\phi = \frac{3}{5}$$

$$\tau_c^{'} = 0.059 \text{ wd}$$

$$0.059\, w_d = WRS_o\sqrt{\frac{1 - \frac{4}{13}}{1 - \frac{9}{25}}}$$

$$\Rightarrow R = \frac{d}{20.87S_o}$$

$$\Rightarrow R = \frac{d}{21S_o}$$

04. Ans: (c)

Sol: $P = 4.75\sqrt{Q}$

$P \propto \sqrt{Q}$

$P_1 = \sqrt{Q}$

$P_2 = \sqrt{1.96Q}$

% increase in wetted perimeter =

$$\frac{\sqrt{1.96Q} - \sqrt{Q}}{\sqrt{Q}} \times 100 = 40\%$$

05. Ans: (b)

Sol: Locey's require sour depth = R_L

$$= 1.35\left(\frac{q^2}{f}\right)^{1/3}$$

$$= 1.35\left(\frac{3^2}{1.2}\right)^{1/3}$$

$$= 1.35\left(\frac{90}{12}\right)^{1/3} = 2.64$$

06. Ans: (b)

Sol: $D_{50} = 0.4$ mm

$f = 1.76\sqrt{D_{50}} = 1.76\sqrt{0.4} = 1.11$

$Q = 40 \text{ m}^3/\text{s}$

$$S = \frac{f^{5/3}}{3340Q^{1/6}} = \frac{1}{5190}$$

07. Ans: (b)

Sol: Perimeter $= b + d\sqrt{5}$

$$= 22 + 2.5\sqrt{5} = 27.59$$

We know $P = 4.75\sqrt{Q}$

$$27.59 = 4.75\sqrt{Q}$$

$$\sqrt{Q} = 5.80$$

$$Q = 33.64$$

09. Ans: (c)

Sol: Average grain size, m = 0.16 mm

Lacey's silt factor, f = ?

$D_{50} = 0.16$

$$f = 1.76\sqrt{D_{50}}$$

$$= 1.76\sqrt{0.16} = 0.704$$

Objective Practice Solutions

05. Ans: (a)

Sol: $Q = 4\ m^3/s$

f = 2

$$V = \left(\frac{Qf^2}{140}\right)^{1/6}$$

$$= \left(\frac{4\times 2^2}{140}\right)^{1/6}$$

$$= 0.6966\ m/s$$

$$A = \frac{Q}{V} = \frac{4}{0.6966} = 5.742$$

$$R = 2.5\frac{V^2}{f} = 2.5\times\frac{0.6966^2}{2} = 0.60$$

$$P = \frac{A}{R} = 9.57$$

$$A = BD + \frac{D^2}{2}$$

$$5.742 = BD + 0.5D^2$$

$$P = B + 2.236D$$

$$D\times 9.57 = BD + 2.236\,D^2$$

$$BD + 0.5D^2 = 5.74$$

$$BD + 2.236D^2 = 9.57D$$

$$1.736 = 9.570 - D$$

$$D = 1.36\ m$$

06. Ans: (c)

Sol: f = 1

$Q = 30\ m^3/s$

S = ?

$$S = \frac{f^{5/3}}{3340Q^{1/6}} = \frac{1}{5887}$$

07. Ans: (a)

Sol:

$V_o = ?$

D = 1.5 m

m = 1.1

N = 0.018

$$V_o = 0.55D^{0.64}$$

$$= 0.55(1.5)^{0.64}$$

$$V_o = 0.713\ m/s$$

08. Ans: (b)

Sol: Perimeter $= b + d\sqrt{5}$

$$= 2 + 8\sqrt{5} = 19.88$$

We know $P = 4.75\sqrt{Q}$

$$19.88 = 4.75\sqrt{Q}$$

$$Q = 17.51$$

Conventional Practice Solutions

02.

Sol: The sediment concentration at a distance 'y' from the bed

$$\frac{C}{C_a} = \left[\frac{a(D-y)}{y(D-a)}\right]^{\frac{w_o}{kV_*}}$$

$$\frac{w_o}{kV_*} = 0.4$$

$$\frac{C}{700} = \left[\frac{2.5(2.8-0.1)}{0.1(0.3)}\right]^{0.4}$$

$\Rightarrow C = 6109$ ppm

a, y measured above the bed

03.

Sol: Lacey's Design

$$Q_{Rabi} = \frac{A}{D} = \frac{A\Delta}{8.64B} = \frac{3600\left(\frac{13.5}{100}\right)}{8.64(28)}$$

=2.008 cumec

$$Q_{khariff} = \frac{A}{D} = \frac{A\Delta}{8.64B} = \frac{1400\left(\frac{19}{100}\right)}{8.64(2.5)(7)} = 1.8 \text{ cumec}$$

$Q_{design} = 2\ m^3/s$

f = 0.85

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{2(0.85)^2}{140}\right)^{1/6} = 0.47 \text{ m/s}$$

$Q = AV \Rightarrow 2 = A\ (0.47)$

$A = 4.255\ m^2$

$$R = 2.5\frac{V^2}{f} = \frac{2.5(0.47)^2}{0.85} = 0.65 \text{ m}$$

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

$$\Rightarrow 0.65 = \frac{4.255}{P} \Rightarrow P = 6.5 \text{ m}$$

$$S = \left[\frac{f^{5/3}}{3340Q^{1/6}}\right] = \frac{0.85^{5/3}}{3340 \times 2^{1/6}} = \frac{1}{4915}$$

$$A = 4.25 = BD + \frac{D^2}{2} \rightarrow (1)$$

$$P = 6.5 = B + 2.236\ D \rightarrow (2)$$

On solving (1) & (2) we get

$$B = 5 \text{ m}, \ D = 0.8 \text{ m}, \ \& \ S = \frac{1}{4915}$$

04.

Sol: $Q = 25\ m^3/s$

f = 1.1

Design of unlined canal by Lacey's theory

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} = 0.775 ms^{-1}$$

$$Q = AV \Rightarrow A = \frac{25}{0.775} = 32.25 m^2$$

$$R = 2.5\frac{V^2}{f} = \frac{2.5(0.775)^2}{1.1} = 1.365 m$$

$$R = \frac{A}{P} \Rightarrow P = \frac{A}{R} = \frac{32.25}{1.365} = 23.63 \text{ m}$$

$$A = BD + \frac{D^2}{2} = 32.25$$

$P = B + 2.236D = 23.63$

$$S = \frac{f^{5/3}}{3340Q^{1/6}} = \frac{1.1^{5/3}}{3340\ \ 25^{1/6}} = \frac{1}{4872}$$

$B = 23.63 - 2.236\ D$

$23.63\ D - 2.236\ D^2 + 0.5D^2 = 32.25$

$1.736\ D^2 - 23.63\ D + 32.25 = 0$

$$D = \frac{23.63\sqrt{23.63^2 - 4(1.736)(32.25)}}{2(1.736)}$$

$$= \frac{23.63 - 18.29}{2(1.736)}$$

$$= \frac{5.34}{2(1.736)} = 1.54\,m$$

$B = 23.63 - 2.236\ D$

$= 23.63 - 2.236\ (1.54)$

$= 20.18$ m

$\Rightarrow B = 20.18$ m

D= 1.54 m

$$S = \frac{1}{4872}$$

05.

Sol: Canal lining is permitted only when Benefit cost ratio exceeds 1.0

Benefits B = B_1+ B_2

B_1 = Benefit due to saving in discharge

B_2 = Benefit due to saving in annual maintenance cost

Costs C = C_1 + C_2

C_1 = Cost due to annual principle amount required for lining

C_2 = Cost due to interest paid on that annual principle amount

Consider 1 km length of canal

Area of wetted perimeter

For LC = 20 × 1000 = 20,000 m^2

For ULC = 25 × 1000 = 25,000 m^2

Seepage loss in LC = $\frac{0.02}{10^6} \times 20000$

$= 4 \times 10^{-4}\ m^3/s$

Seepage loss in ULC

$$= \frac{2.5}{10^6} \times 25000 = 0.0625\ \ m^3/s$$

Saving in Q = (625 – 4) 10^{-4} = 621 × 10^4 m^3/s

1 m^3/s water saved = 25 lakhs rupees

$\therefore$ Annual seepage saved

$= 621 \times 10^{-4} \times 25 \times 10^5$

B_1 = 155250 rupees

B_2 = AMC of ULC = 1 × 25000 = 25,000 Rs

Saving in AMC = $\frac{40}{100}[25000] = 10{,}000$ Rs

B_2 = 10000 Rs

B = 155250 + 10000 = 165250 Rs

Cost $C_1 \Rightarrow$ Per m^2 cost Rs 100/-

$= 2 \times 10^6$ Rs

Per 50 years

$$C_1 = \frac{2\times10^6}{50} = 40,000$$

$$C_2 = \text{Its interest} = \frac{PNR}{200} = \frac{40000\times1\times6}{200}$$

$$= 1200$$

$C = C_1 + C_2 = 41,200$ Rs

$$\frac{B}{C}\text{ratio} = \frac{B}{C} = \frac{165250}{41200} = 4$$

As $\frac{B}{C}$ ratio exceeds 1

Canal lining is justified.

06.

Sol: Tractive force approach:

Given data: Q = 45 cumec

$S = \frac{1}{4800}$, N = 0.0225

Permissible tractive stress

$\tau_c = 0.0035$ kPa

As it is unlined canal, side slope is fixed at $\frac{1}{2}H:1V$

Tractive stress $\tau_c = wRS$

$$0.0035 \times 10^3 = 1000 \times 9.81\times R \times \frac{1}{4800}$$

$$R = 1.712 \text{ m}$$

$$Q = AV = A\,\frac{1}{N}R^{2/3}\,S^{1/2}$$

$$45 = A\frac{1}{0.0225}(1.712)^{2/3}\left(\frac{1}{4800}\right)^{1/2}$$

$A = 49.02$ m^2

$$R = \frac{A}{P} \Rightarrow P = \frac{A}{R} = \frac{49.02}{1.712} = 28.63\,\text{m}$$

$$A = BD + \frac{D^2}{2} = 49.02$$

P = B + 2.236 D = 28.63

Solving , B = 24.3 m

D = 1.95 m

07.

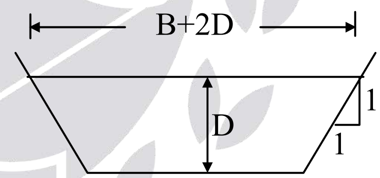
Sol: Design of regime channel

Q = 40 m^3/s

Side slope 1 : 1

Shape is trapezoidal

D_{50} = 0.8 mm



$$A = (B + B + 2D)\ \frac{D}{2} = BD + D^2$$

$$P = B + 2\sqrt{2}D = B + 2.828D$$

$$f = 1.76\sqrt{D_{50}} = 1.574$$

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{40(1.574)^2}{140}\right)^{1/6} = 0.944\ \text{m}$$

$Q = AV \Rightarrow 40 = A\ (0.944)$

$A = 42.37$ m^2

$R = 2.5\ V^2/f = 1.415$ m

$$R = \frac{A}{P} \Rightarrow P = \frac{A}{R} = \frac{42.37}{1.415} = 30\ \text{m}$$

$BD + D^2 = 42.4$

$B + 2.828\ D = 30$

$B = 25.6$ m

$D = 1.6$ m

$$S = \frac{f^{5/3}}{3340Q^{1/6}} = \frac{1.574^{5/3}}{3340 \times 40^{1/6}} = \frac{1}{2900}$$

$\therefore$ B = 25.6 m

D = 1.6 m

$$S = \frac{1}{2900}$$

08.

Sol: Design of irrigation channel by Kennedy's theory:

$Q = 50\ m^3/s$

$$\frac{B}{D} = 2.5$$

m = 1.1

N = 0.025

$$Z = \frac{1}{2}H : 1V \Rightarrow A = BD + \frac{D^2}{2}$$

$$P = B + 2.236\,D$$

$$A = BD + \frac{D^2}{2}$$

$$= 2.5D^2 + 0.5D^2 = 3D^2 \rightarrow (1)$$

$V = 0.55\ m\ D^{0.64}$

$= 0.55\ (1.1)\ D^{0.64} = 0.605\ D^{0.64} \rightarrow (2)$

Q = AV

$50 = 3D^2\ (0.605)\ D^{0.64}$

$$D^{2.64} = \frac{50}{3(0.605)} \Rightarrow D = 3.5\ \text{m}$$

B = 8.75 m = 2.5 D

$V = 0.55\ m\ D^{0.64}$

$= 0.55 \times 1.1 \times 3.5^{0.64} = 1.35$ m/s

Applying Kutter's formula

$$R = \frac{A}{P} = \frac{BD + \frac{D^2}{2}}{B + 2.236D} = \frac{36.75}{16.326} = 2.251\ \text{m}$$

$V = C\sqrt{RS}$

$$\text{Where } C = \frac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{N}{\sqrt{R}}}$$

$$1.35 = \left[\frac{\frac{1}{0.025} + 23 + \frac{0.00155}{S}}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{0.025}{\sqrt{2.251}}}\right]\sqrt{2.251S}$$

Solving by Trial & error method

$$S = \frac{1}{2590}$$

$\therefore$ B = 8.75 m

D = 3.5 m

$$S = \frac{1}{2590}$$

07. Water Logging and Drainage

Conceptual Solutions

03. Ans: (a)

Sol: $P_H > 7 \Rightarrow$ alkaline

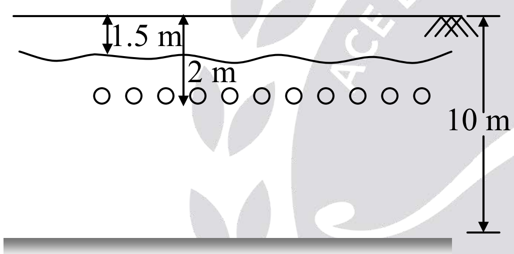
$P_H < 7 \Rightarrow$ acidic

Gives $P_H = 9.5 \Rightarrow$ the soil is alkaline.

Conventional Practice Solutions

02.

Sol:



$b = 10 - 1.5 = 8.5$ m

$a = 10 - 2.0 = 8.0$ m $L = ?$

$K = 6 \times 10^{-6}$ m/s

$\overline{P} = 96$ cm $= 96 \times 10^{-2}$ m

$$D_c = \frac{\overline{P}}{100}\frac{L}{86400} = \frac{4K\left(b^2 - a^2\right)}{L}$$

$$\Rightarrow L^2 = \frac{4(864)10^4 K\left(b^2 - a^2\right)}{\overline{P}}$$

$$L = \sqrt{\frac{4(864)10^4 K\left(b^2 - a^2\right)}{\overline{P}}}$$

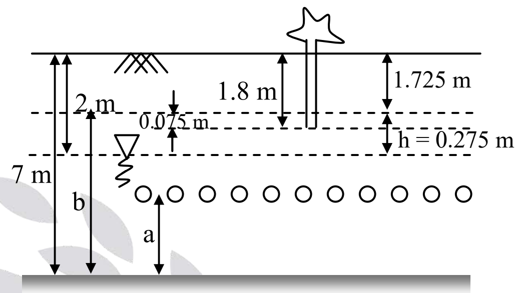
$$= \sqrt{\frac{4(864)10^4\left(6\times10^{-6}\right)\left(8.5^2 - 8^2\right)}{96\times10^{-2}}}$$

$$= \sqrt{216\times\frac{33}{4}} = 42.2 \text{ m}$$

Spacing of tile drains = 42.2 m

03.

Sol:



$$h = \text{capillarity height} = \frac{4t\cos\theta}{\rho g d}$$

$$= \frac{4(0.054)\cos 0^\circ}{1000(9.81)\left(8\times10^{-5}\right)} = 0.275 \text{ m}$$

RZD + Capillary height = 1.8 + 0.275

= 2.075 m

GWT is at 2 m

∴ Roots will reach the capillary saturated zone by 7.5 cm

∴ Filed is slightly water logged

(b) $q = D_c$

$$\frac{4k\left(b^2 - a^2\right)}{L} = D_c$$

$b = 7 - 1.725$

$= 5.275$ m

$a = ?$

$$\frac{4\times10^{-6}\left(5.275^2 - a^2\right)}{15} = 0.116\times10^{-6}\times15\times1$$

$\Rightarrow a^2 = 21.3$

$a = 4.61$ m

Centre of tile drain is at 4.61 m above impervious stratum.

04.

Sol: Two water logged areas

$$\frac{K_A}{K_B}=\frac{2}{1}\quad \frac{L_A}{L_B}=\frac{2}{3}\quad \frac{\left(b^2-a^2\right)_A}{\left(b^2-a^2\right)_B}=\frac{5}{6}$$

(i) $$q=\frac{4K\left(b^2-a^2\right)}{L}$$

$$\frac{q_A}{q_B}=\frac{K_A}{K_B}\frac{\left(b^2-a^2\right)_A}{\left(b^2-a^2\right)_B}\frac{L_B}{L_A}$$

$$=\frac{2}{1}\times\frac{5}{6}\times\frac{3}{2}=\frac{5}{2}=2.5$$

(ii) $$q=\frac{\overline{P}}{100}\frac{L}{1\text{day}}$$

$$\frac{q_A}{q_B}=\frac{\overline{P}_A}{\overline{P}_B}\frac{L_A}{L_B}$$

$$\frac{5}{2}=\frac{\overline{P}_A}{P_B}\frac{2}{3}$$

$$\Rightarrow \frac{\overline{P}_A}{\overline{P}_B}=\frac{15}{4}=3.75$$

08. Cross Regulatory Works, Canal outlets & Cross Drainage Works

Conceptual Solutions

12. Ans: (c)

Sol: $$S_e=\frac{m}{n}=\frac{\frac{1}{2}}{\frac{5}{3}}=\frac{1}{2}\times\frac{3}{5}=\frac{3}{10}=0.3$$

22. Ans: (c)

Sol: $$S=\frac{\frac{dq}{q}\times 100}{\frac{dD}{D}\times 100}$$

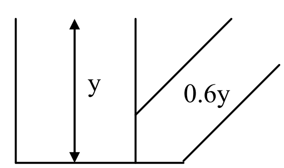
$$\frac{1}{2}=\frac{\frac{dq}{q}\times 100}{50}$$

$$\frac{dq}{q}=25\%$$

Objective Practice Solutions

02. Ans: (b)

Sol:



$y - 0.4y$
$= 0.6y$

$$S_e=\frac{H}{D}=\frac{0.6y}{y}$$

$$\Rightarrow S_e = 0.6$$

06. Ans: (c)

Sol: (Canal) $Q_C > Q_d$ (drainage)

Type II Siphon (or) canal siphon

Conventional Practice Solutions

03.

Sol: Submerged pipe outlet diameter (d)

$Q = C_d A\sqrt{2gH}$

H = FSL of minor distributory

- FSL of field channel

= 100 – 99.9 = 0.1 m

$Q = 0.04\ m^3/s$

$C_d = 0.7$

$Q = C_d\ A\ \sqrt{2gH}$

$0.04 = 0.7\ \times A\sqrt{2(9.81)(0.1)}$

$A = 0.0408\ m^2$

$\frac{\pi d^2}{4} = 0.0408$

d = 0.2279 m

= 22.8 cm

09. Diversion Head Works

Conceptual Solutions

06. Ans: (b)

Sol:

K = m

C = m

$L = (6+6) + \frac{36}{3} + (10+10)$

L = 44 m

H = 4 m

$C_L = \frac{L}{H} = \frac{44}{4}$ =11 m

At mid point

$\ell_{m.p} = 12 + \frac{18}{3}$

= 18 m

$h'_{M.P} = \frac{\ell_{MD}}{C_L} = \frac{18}{11} = 1.64$ m

$h_{m.p} = H - h'_{M.P}$

= 4 – 1.64 m

= 2.36 m

16. Ans: (b)

Sol: $P_e = \frac{P}{\gamma} + Z + h$

10 = 2 + 3+ h

10 = 5+h

h = 5 m

$t_{min\ bottom} = \frac{h}{s_c}$

$= \frac{5}{2.5} = 2$ m

17. Ans: (b)

Sol: Floor thickness with suitable F.O.S (2.4) is

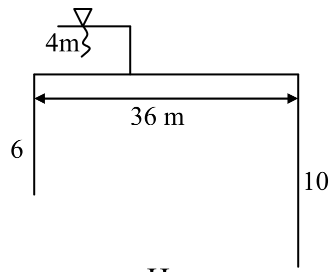
$= \frac{4}{3} \times \frac{h}{s-1}$

$= \frac{4}{3} \times \frac{2.8}{2.4-1} = 2.66 \equiv 2.67$

Objective Practice Solutions

02. Ans: (a)

Sol:



$$G_E = \frac{H}{d\pi\sqrt{\lambda}}$$

$$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2};\quad \alpha = \frac{b}{d} = \frac{54}{6} = 9$$

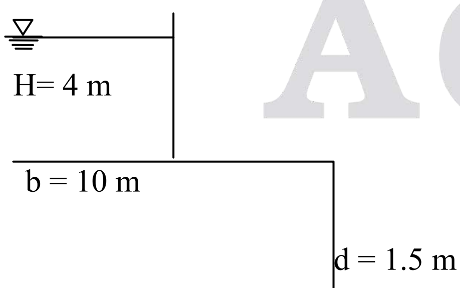
$$\frac{1+\sqrt{1+81}}{2} = 5.02$$

$$G_E = \frac{6}{6\times\pi\times\sqrt{5.02}} = \frac{1}{\pi\times\sqrt{5.02}}$$

Conventional Practice Solutions

03.

Sol:



$$\alpha = \frac{b}{d} = \frac{10}{1.5} = 6.66$$

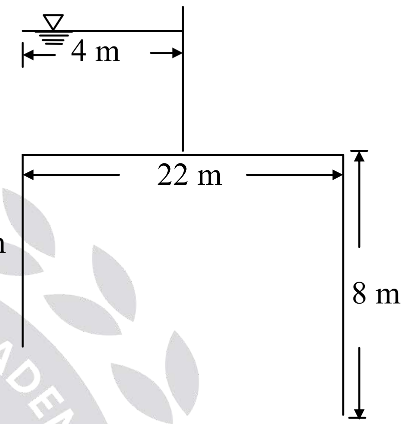
$$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2} = 3.87$$

$$G_E = \frac{H}{d}\frac{1}{\pi\sqrt{\lambda}} = \frac{4}{1.5}\frac{1}{\pi\sqrt{3.87}}$$

$$= 0.43$$

05.

Sol:



By Bligh's Theory

L = 6(2) + 22 + 2(8)

= 50 m

H = 4 m

$$C = \frac{L}{H} = \frac{50}{4} = 12.5$$

Average hydraulic gradient

$$i = \frac{1}{C} = \frac{4}{50} = 0.08$$

(b) At 6 m from U/S end

l = 12 + 6 = 18 m

$$h' = \frac{\ell}{C} = \frac{18}{12.5} = 1.44\text{m}$$

h = H – h′ = 4 – 1.44 = 2.56 m

$$t_{min} = \frac{4}{3}\frac{h}{S_c - 1} = \frac{4}{3}\frac{2.56}{(2.24-1)}$$

$$= 2.76 \text{ m}$$

At 12 m from U/S end

$l = 12 + 12 = 24$ m

$$h' = \frac{\ell}{C} = \frac{24}{12.5} = 1.92\,m$$

$$h = H - h' = 4 - 1.92 = 2.08\,m$$

$$t_{min} = \frac{4}{3}\frac{h}{S_c - 1} = \frac{4}{3}\frac{2.08}{(2.24-1)} = 2.236\,m$$

At 18 m from U/S end

$L = 12 + 18 = 30$ m

$$h' = \frac{\ell}{C} = \frac{30}{12.5} = 2.4\ m$$

$$h = H - h' = 4 - 2.4 = 1.6\ m$$

$$t_{min} = \frac{4}{3}\frac{h}{S_c - 1} = \frac{4}{3}\frac{1.6}{2.24-1} = 1.72\ m$$

10. River Training Works

Conceptual Solutions

02. Ans: (b)

Sol: $Q = 1600\ m^3/s$

Meander belt $= 153.75\sqrt{Q}$

$= 153.75\sqrt{1600}$

$= 6150$ m

i.e., the order of 6 km

03. Ans: (b)

Sol: $Q = 6000\ m^3/s$ $\quad M_w = 153.75\ \sqrt{Q}$

$M_L = 53.75\ \sqrt{Q}$ $\quad M_R = \frac{M_W}{m_L} = 2.97 \quad \approx 3$

04. Ans: (d)

Sol:

Meander belt $= 153.75\sqrt{Q} = 3000$ m

$$\sqrt{Q} = \frac{3000}{153.75}$$

$\Rightarrow Q = 380.72$ cumec

$Q_{peak} = 2\overline{Q} = 760$ cumec

i.e., the order of 700cumec

06. Ans: (a)

Sol: $Q = 1600$ cumec

$P = 4.75\sqrt{Q}$

$= 4.75\sqrt{1600}$

$= 190$ m

11. Dams General Principles

Conceptual Solutions

06 Ans: (a)

Sol: Rate of silt deposition per year

$= 0.1\ Mm^3$/year

Capacity of reservoir $= 30\ Mm^3$

Silt storage capacity = 20% capacity

$$= \frac{20}{100}\times 30 = 6\ Mm^3$$

$$\text{Life of reservoir} = \frac{6}{0.1} = 60\,\text{years}$$

12. Gravity Dams

Conceptual Solutions

08. Ans: (a)

Sol: $\mu = 0.75$

$\sum PV = 6000$ t

$\sum P_H = 5000$ t

$b = 70$ m

$q = 140$ t/m^2

$$\text{F.O.S against sliding} = \frac{\mu.\sum P_V}{\sum P_H}$$

$$= \frac{0.75\times6000}{5000} = 0.9$$

(b)

Sol: $$SFF = \frac{\mu\sum P_V + b.q}{\sum P_H}$$

$$SFF = \frac{0.75\times6000+70\times140}{5000} = 2.86$$

11. Ans: (d)

Sol: For F > 32 km, the wave is given by equation given below

$$h_w = 0.032\sqrt{V.F}\ \text{m}$$

$$= 0.032\times\sqrt{160\times4} = 2.56\ \text{m}$$

Force caused by waves P_w is given by equation

$P_w = 19.62\ h_w^2$ kN/m run of dam

$= 19.62 \times (2.56)^2$ kN = 128.6 kN

≈ 130 kN

13. Ans: (c)

Sol: Wave height

$(h_w) = 0.032\sqrt{V.F} + 0.763 - 0.271(F)^{1/4}$ for F < 32 km

$$h_w = 0.032\sqrt{100\times20} + 0.763 - 0.271(20)^{1/4}$$

$$= 1.62\ \text{m}$$

Free board generally provided equal to

$1.5\ h_w = 1.5 \times 1.62 = 2.45$ m ≈ 2.5 m

16. Ans: (d)

Sol: $$B = \frac{H}{\sqrt{S-C}} = \frac{60}{\sqrt{2.4-1}} = \frac{60}{\sqrt{1.4}}$$

$= 50.7$ m

(with full uplift pressure C = 1) → (1)

$$B = \frac{H}{\mu(S-C)} = \frac{60}{0.7(1.4)} = 61.22\text{m} \approx 61\text{m} \rightarrow (2)$$

From (1) and (2) which is greater i.e. 61 m

Objective Practice Solutions

04. Ans: (c)

Sol: Limiting height (or) critical height of a dam

$$H_c = \frac{f}{\gamma_w(G+1)} = \frac{2500}{10(2.4+1)} = 73.52\,\text{m}$$

05. Ans: (d)

Sol: Limitting height at low dam with our considering uplift $H_V = \dfrac{f}{w(s-G+1)}$

$$= \frac{f}{w(2.5-0+1)} = \frac{f}{w(3.5)}$$

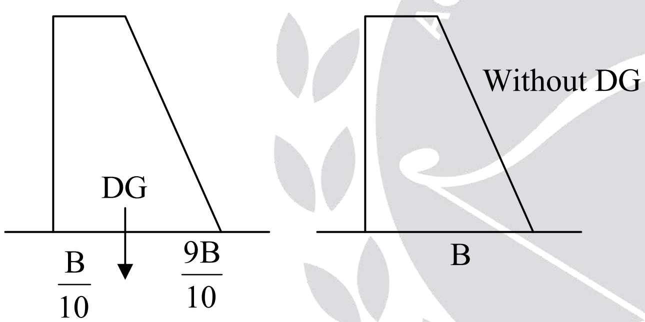
Limitting height at low dam with our considering uplift $H_S = \frac{f}{w(s-G+1)}$

$$= \frac{f}{w(2.5-1+1)} = \frac{f}{w(2.5)}$$

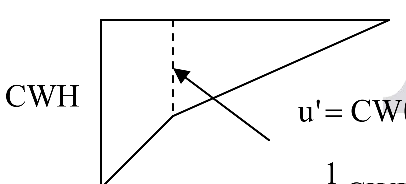
Ratio of $\frac{H_S}{H_v} = \frac{\frac{f}{w(2.5)}}{\frac{f}{w(3.5)}} = \frac{3.5}{2.5} = 1.4$

06. Ans: (d)

Sol:



1. With drainage gallery



$$u' = CW(O) + \frac{1}{3}CWH$$

$$= \frac{1}{3}CWH$$

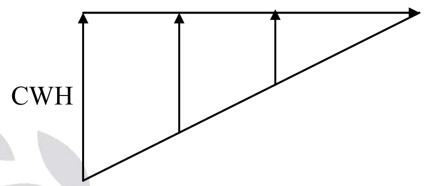
$$U_1 = \frac{B}{10(2)}\left[CWH + \frac{1}{3}CWH\right] + \frac{9B}{10(2)}\frac{CWH}{3}$$

$$= \frac{B}{20}\left(\frac{4}{3}CWH\right) + \frac{9B}{20}\frac{CWH}{3}$$

$$= 13\frac{CWHB}{60}$$

2. Without drainage gallery

$$U_2 = \frac{1}{2}BCWH$$



Reduction in uplift force in case of DG

$$= CWHB\left[\frac{1}{2} - \frac{13}{60}\right] = CWHB\left[\frac{17}{60}\right]$$

% Reduction

$$= \frac{\frac{17}{30}CWHB \times 100}{\frac{1}{2}CWHB} = 56.67\%$$

07. Ans: (A)

Sol: $SFF = \frac{M\sum V + bq}{\sum H}$

$\sum H = 70$

Factor of safety against sliding $= \frac{\mu.\sum V}{\sum H}$

$$1.05 = \frac{\mu.\sum V}{70}$$

$\mu.\sum V = 72.8$

$q = 1.4$ MPa

$b = 70$ m

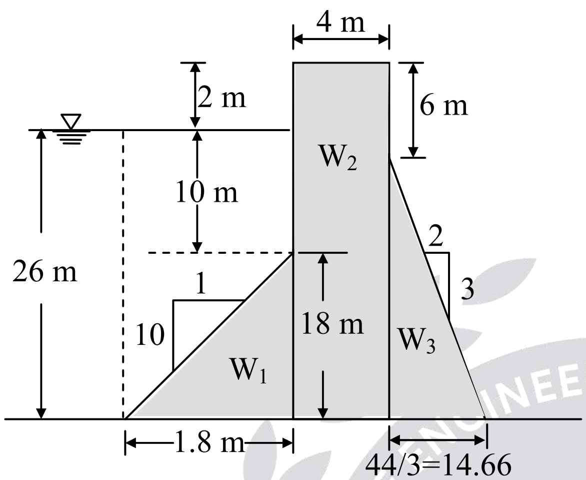
$$SFF = \frac{72.8 + 70 \times 1.4}{70}$$

SFF = 2.44

Conventional Practice Solutions

03.

Sol:



Ice force, wind force, seismic force need not be considered.

No Tail water therefore $P_2 = 0$

Only W, P, & U are to be considered.

W : $W = W_1 + W_2 + W_3$ as shown in figure consider 1 m length of dam

$$W_1 = \frac{1}{2}1.8(18)(26.4) = 427.68 \text{ kN}$$

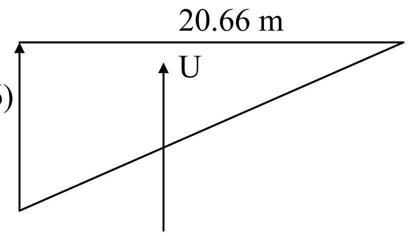
$$W_2 = 4(28)(26.4) = 2956.8 \text{ kN}$$

$$W_3 = \frac{1}{2}\frac{44}{3}(22)(26.4) = 4259.2 \text{ kN}$$

$$P_1 = \frac{wH_1^2}{2} = \frac{10(26)^2}{2} = 3380 \text{ kN}$$

W_w = Weight of water on u/s side

$$= \left(\frac{26+8}{2}\right)1.8(10) = 306 \text{ kN}$$



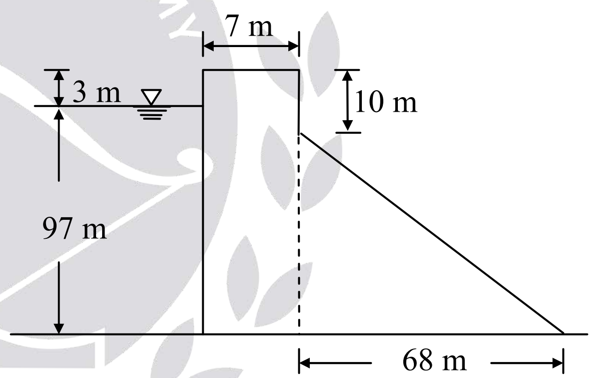
$$U = \frac{1}{2}(20.66)(182) = 1880 \text{ kN}$$

$\Sigma V = W - U + W_w = 6070$ kN

$\Sigma H = P = 3380$ kN

04.

Sol: For safety against sliding FSS > 1.0



$\mu = 0.75$

$\gamma_c = 2.4$ t/m^3

$\gamma_w = 1$ t/m^3

$W_1 = 7 \times 100 \times 1 = 700$ t

$$W_2 = \frac{1}{2}68(90)\times 1 = 3060\text{t}$$

$W = W_1 + W_2 = 3760$ t

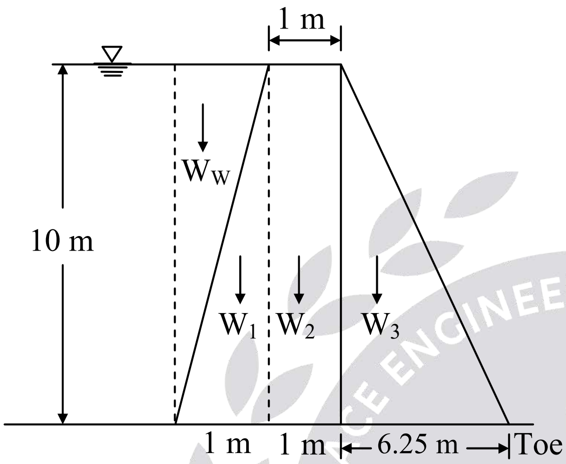
$$\Sigma H = P = \frac{wH^2}{2} = \frac{1(97)^2}{2} = 4704.5$$

$$FSS = \frac{\mu \Sigma V}{\Sigma H} = \frac{0.75(3760)}{4704.5}$$

$= 0.6 < 1$ Not safe

05.

Sol:



$$W_1 = \frac{1}{2}(1)(10)22.4 = 112 \text{ kN}$$

$$x_1 = 7.25 + \frac{1}{3}$$

$= 7.58$ m from toe

$W_2 = 10(1)\ 22.4 = 224$ kN

$$x_2 = 6.25 + \frac{1}{2}$$

$= 6.75$ m from toe

$$W_3 = \frac{1}{2}(6.25)10(22.4) = 700 \text{ kN}$$

$$x_3 = \frac{2}{3}(6.25)$$

$= 4.16$ m from toe

$W = W_1 + W_2 + W_3$

$= 112 + 224 + 700 = 1036$ kN

$M_w = W_1x_1 + W_2x_2 + W_3x_3 = 5272.96$ kN-m

$$P = \frac{wH^2}{2} = \frac{10(10)^2}{2} = 500 \text{ kN}$$

At $\frac{10}{3} = 3.33$ m from toe

$$W_w = \frac{1}{2}1(10)(10) = 50 \text{ kN}$$

Acting at $7.25 + \frac{2}{3}(1) = 7.91$m from toe

$\Sigma H = P = 500$ kN

$\Sigma V = W + W_w = 1036 + 50 = 1086$ kN

$$FSS = \frac{\mu \Sigma V}{\Sigma H} = \frac{0.75(1086)}{500} = 1.63 > 1 \text{ (Safe)}$$

$$SFF = \frac{\mu \Sigma V + bq}{\Sigma H} = FSS + \frac{bq}{\Sigma H}$$

$$= 1.63 + \frac{8.25(14)}{500} \times 9.81 \times 10^{-3} \times 10^4$$

Safe = 24.3 > 2

$$FSOT = \frac{\Sigma M_R}{\Sigma M_o} = \frac{5272.96 + 50(7.91)}{500(3.33)}$$

= 3.4 (Safe)

13. Spillways

Conceptual Solutions

06. **Ans: (b)**

Sol: If initial head is H

Increased head by 125% ⇒ H + 1.25H

= 2.25 H

Q for ogee spill way = $C \times L_e \times H_e^{3/2}$

$Q \propto H_e^{3/2}$

$Q_1 = (H_1)^{3/2}$

$Q_2 = (2.25H_2)^{3/2} = 3.375H^{3/2}$

% increased in discharge = $\frac{Q_2 - Q_1}{Q_1} \times 100$

$= \frac{3.375H^{3/2} - H^{3/2}}{H^{3/2}} \times 100 = 237.5\%$

12. Ans: (9.96)

Sol: $L_e = L - 2H_d[K_A + (n-1)K_P]$

n = no. of spans

= 10 – 2(0.6) [0.1 + 2(0.1)]

n – 1 = no. of piers

= 10 – 0.36 = 99.64 cms

= 9.96 mts

Conventional Practice Solutions

01.

Sol: q = 1 m^2/s, C_d = 0.7

$q = \frac{2}{3}C_d\sqrt{2g}H^{3/2} \Rightarrow h = 0.62\text{ m}$

Height of crest above floor level = 10 m

Total height = $10 + \frac{0.62}{2} = 10.31\text{ m}$

Theoretical velocity at foot of spillway

$= \sqrt{2gH} = \sqrt{29.81 \times 10.31}$ = 14.22 m/s

Assume C_v = 0.9

V_1 = 0.9 × 14.22 = 12.80 m/s

At the foot of spillway, $y_1 = \frac{q}{V_1} = \frac{1}{12.80} = 0$

$F_{r_1} = \frac{V_1}{\sqrt{gy_1}} = \frac{12.80}{\sqrt{9.81 \times 0.078}} = 14.62 > 1$

Flow will be supercrititcal

Depth of flow on d/s, y_2 = 1 m

$V_2 = \frac{q}{y_2} = \frac{1}{1} = 1\text{ m/s}$

$F_{r_2} = \frac{V_2}{\sqrt{gy_2}} = \frac{1}{\sqrt{9.81 \times 1}} = 0.32 < 1$

Subcritical

∴ Hydraulic jump will be formed

$y_2 = \frac{y_1}{2}\left[-1 + \sqrt{1 + 8Fr_1^2}\right] = 1.574$

But depth available in the stream at d/s = 1.0 m

∴ The stilling basin has to be depressed by

1.574 – 1.0 = 0.574 m

Length of stilling basin

= 5 ($y_2 - y_1$) = 5 (1.574 – 0.078)

= 7.5 m

03.

Sol: Given data

H = 20 m

Slope of U/S face = 1 : 1.5 (H : V)

K = 1.939, n = 1.81

Ogee spillway downstream profile

$x^n = kH^{n-1}y$

$H_e = H_d + H_a$

H_a : Due to velocity of approach (negligible)

O : Origin at highest point C of crest

n = 1.81

k = 1.939

$x^{1.81} = 1.939 \times 20^{1.81-1}\ y$

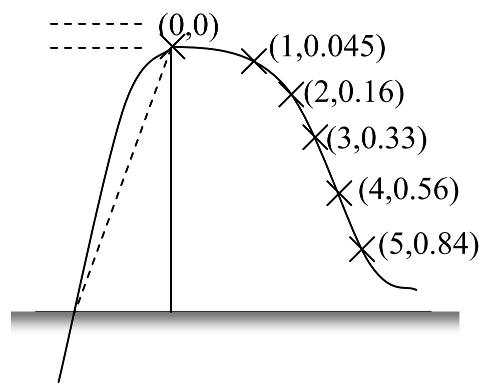
$\Rightarrow x^{1.81} = 21.95\ y$

Profile of ogee spillway upstream profile can extend upto

$x = -0.27\ H_d$

$= -0.27\ (20) = -5.4$ m

x	y
1	0.042 m
2	0.16 m
3	0.33 m
4	0.56 m
5	0.84 m
6	1.17 m
7	1.54 m
8	1.96 m
9	2.43 m
10	2.94 m



05.

Sol: $y_1 = 0.8$ m

Tail water depth = 6 m

$q = 10\ m^2/s$

$$y_2 = \frac{-y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2q^2}{gy_1}}$$

$$= \frac{-0.8}{2} + \sqrt{\frac{0.8^2}{4} + \frac{2(100)}{9.81 \times 0.8}} = 4.664 \text{ m}$$

With 7% margin for sweep out caused by jumping water on tail water

$y_2 = 1.07 \times 4.664 = 4.99$ m

$\therefore$ Tail water depth = 6 m, is more than $y_2 = 4.99$ m

$\therefore$ The jump to be formed will get drowned out by tail water and proper energy dissipation will not occur.

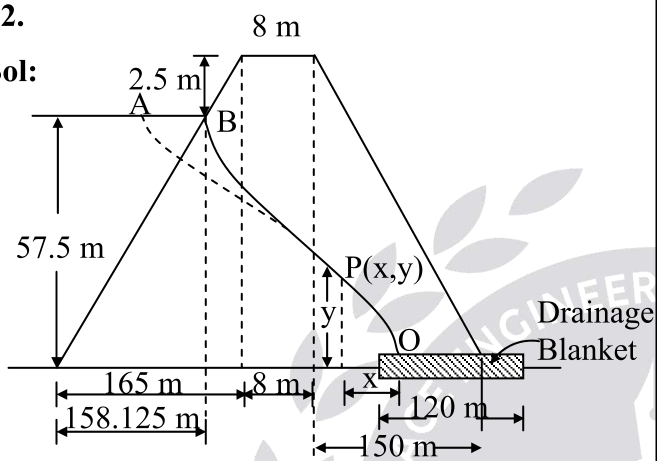
$\therefore$ Point of jump formation will have to be raised by providing a sloping glacier apron.

14. Earth Dams

Conventional Practice Solutions

02.

Sol:



F is focus and origin (0, 0)

The curve shown of phreatic line is a parabola. Any point on parabola is equidistant from focus & directrix

Distance of directrix from focus = S

Any point P on the parabola (x, y)

$\Rightarrow x + s\ \sqrt{x^2 + y^2}$

$x^2 + s^2 + 2xs = x^2 + y^2$

$y = \sqrt{s^2 + 2xs}$

Point A lies on curve with x

= 47.4375 + 165 – 158.125 + 8 + 150 – 120

= 92.3125

y- coordinate = 57.5 m

$s = \sqrt{x^2 + y^2} - x$

$= \sqrt{92.3125^2 + 57.5^2} - 92.3125$

= 16.44 m

As per Darcy's law:

$$i = \frac{dy}{dx} \Rightarrow y = \sqrt{s^2 + 2xs}$$

$$\frac{dy}{dx} = \frac{2s}{2\sqrt{s^2 + 2sx}}$$

$$= \frac{s}{\sqrt{s^2 + 2sx}}$$

$$q = k\frac{dy}{dx}y = \sqrt{k_x k_y}\frac{s}{\sqrt{s^2 + 2xs}}\sqrt{s^2 + 2sx}$$

$$= \sqrt{k_x k_y}\ s$$

$$= \sqrt{4 \times 10^{-7} \times 10^{-7}}(16.44)$$

$= 3.3 \times 10^{-6}$ m^2/s