GATE | PSUs

CIVIL ENGINEERING

Irrigation Engineering

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

Irrigation Engineering

(Solutions for Text Book Practice Questions)

01. Basics of Water Resources Engineering

Practice Solutions

02. Ans: (a)

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

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

$$A_{max} = \frac{Q}{f} = \frac{50\times10^{-3}}{5\times10^{-2}}\times3600$$

$$= 3600\ m^2$$

1 ha = 10000 m^2

1 ha = 10^4 m^2

In hectares = 3600 × 10^{-4} hectares

= 0.36 ha

03. Ans: (a), (c) & (d)

Sol: Sprinkler Method:

- In this method, irrigation water is applied to land in the form of spray, some what as ordinary rain through a network of pipes and pumps.
- This system is flexible and suitable to undulating topography (hilly areas) and hence land levelling is not required and as land leveling is not required labour cost is reduced.
- As surface runoff is eliminated, erosion can be controlled.
- Sprinkler irrigation can be used for all crops except rice and jute because for them, standing water is necessary.

04. Ans: (a) & (c)

Sol: Furrow irrigation:

- In this method of irrigation, water is applied to land to be irrigated by series of furrows.
- Water flowing in furrows infiltrates into the soil and spread laterally to irrigate the land between furrows.

Check flooding

- For check flooding method, deep homogeneous loam and clay soils with medium infiltration rates are prettered.
- This method is suitable for both more permeable and less permeable soil.

02. Soil, Water and Plant

Practice Solutions

01. Ans: (b)

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

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

$d_w = c_u$

$d_w = Sd[FC - OMC]$

$= 1.3 \times 70\ [0.28 - 0.16]$

$= 10.92$ cm

Note:

In this problem time frequency is taken as 1 day $\Rightarrow f = 1$

02. Ans: (c)

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

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

$= 1.3$

$y = Sd[FC - pwp]$

$= 1.3 \times 80\ [35 - 0.2]$

$y = 15.6$ cm

03. Ans: (a), (b), (c) & (d)

Sol: Soil moisture constants:

i. Saturation Capacity:

- Saturation capacity is defined as the total water content of a soil when all the pores of soil are filled with water.
- This is know as maximum water holding capacity of soil.
- At saturation capacity, soil moisture tension is almost zero, as it is equal to surface tension at free water surface.

ii. Filed capacity:

Soil moisture tension at field capacity ranges between 1/10 to 1/3 atmospheric.

iii. Permanent wilting point:

Soil moisture tension varies 7-32 atm

04. Ans: (a), (b) & (c)

Sol: Following crop ration:

i. Wheat – Juar- Gram

ii. Rice – Gram

iii. Cotton – Wheat – Gram - Fallow (upto july)

iv. Cotton - Juar – Gram

v. Sugarcane (18 month) – Thadwa – Wheat or Gram Fallow (upto july)

05. Ans: (a), (b), (c) & (d)

Sol: Soil fertility is maintained by keeping the land fallow, addition of manure and fertilizer, crop rotation, intercropping.

03. Water Requirement of Crops

Conceptual Solutions

08. Ans: (d)

Sol: $\Delta_{Kor} = 15.12$ 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: $\textbf{Volume}_{canal} = \text{Area} \times y_{canal}$

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

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

$= 11, 111.11\ m^3$

19. Ans: (d)

Sol: The annual intensity of irrigation for this state

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

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 hectares

03. Ans: (c)

Sol: Base period = 90 days

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

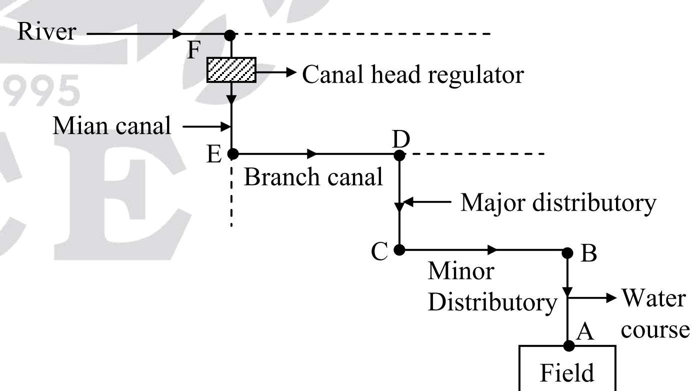
$$= 8.64\times\frac{90}{(105-15)}$$

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

= 864 ha / m^3

04. Ans: (a) & (c)

Sol:



$D_A > D_B > D_C > D_D > D_E > D_F$

Hence option A is wrong.

By lining the canal, transmission losses can be reduce duty can be improved.

Capacity factor: $\frac{Q_{mean}}{Q_{max}}$

Paleo water: It is first water given to field before sowing the crop to prepare land.

Kor watering: It is first watering given to crop, when it is few cm high.

05. Ans: (a) & (c)

Sol: crop area = 3000 ha

F.C = 26%,

OMC = 12%

PWP = 10%

Root zone depth (d) = 80 cm,

S.G = 1.4

Frequency of irritation = 10 days

Depth of water used by plants for growth which is supplied at 10 days interval,

$$d = \frac{\gamma_d}{\gamma_w} \times d\ (F.C - OMC)$$

d = 1.4 × 0.8(0.26 – 0.12) = 15.68 cm

$$\text{daily consumptive use} = \frac{15.68}{10} = 1.56 \text{ cm}$$

Water storage capacity

$$= \frac{\gamma_d}{\gamma_w} \times d \times (F.C - PWP)$$

= 1.4 × 0.8 × [0.26 – 0.10)

= 17.92

$$\text{Discharge} = \frac{1.568 \times 10^{-2}\ m \times 3000 \times 10^4\ m^2}{\text{day}}$$

$Q = 5.44\ m^3/sec$

06. Ans: (a), (b) & (c)

Sol: With increase in water supply, it may create water logging and hence decrease the yield of crop.

04. Quality of Irrigation Water

Conceptual Solutions

05. Ans: (c)

Sol: Na^+ = 345ppm

Ca^{++} = 60 ppm

Mg^{++} = 18 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)

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

$$= \frac{15}{\sqrt{\frac{2+1.5}{2}}} = 11.33$$

Practice Solutions

01. Ans: (a) & (b)

Sol: **Sodic Soil:** Sodic soil is defined as a soil with an exchangeable sodium of greater than 6% of the cations exchange capacity. Sodic soil contains measurable quantity of sodium carbonate which imparts to these soil a high pH always more than 8.2, when measured on a saturated soil paste and upto 10.8 or so when appreciable quantities of free sodium carbonate are present.

Saline alkali soil has EC value > 4000 μ mho/cm (i.e. 4 milli mho/cm) and ESP of greater than 15

02. Ans: (a), (b), (c) & (d)

Sol: High concentration of salt may result in dehydration of plants due to osmotic effect and water having pH of 0 – 8.5 is preferable for irrigation purpose.

05. Design of Lined Canals

Conceptual Solutions

03. Ans: (a)

Sol: Given channel is triangular lined channel

$\Rightarrow$ 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

$26 = 13 \times V$

V = 2m/s

Considering F.O.S as 1.1

$\Rightarrow V = 2 \times 1.1 = 2.2$

Practice Solutions

01 Ans: (c)

Sol: y = 4 m

R = ?

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

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

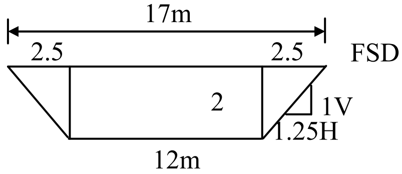
$R = \frac{A}{P} = \frac{y^3(\theta + \cot\theta)}{2y(\theta + \cot\theta)}$

y = 4 m

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

02. Ans: (c)

Sol:



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

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

$$= 18.40$$

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

04. Ans: (a), (b) & (d)

Sol: Various type of lining.

(a) Hard surface lining.

- i. Cast in situ cement concrete lining.
- ii. Shotcrete or plaster lining
- iii. Cement concrete tile lining or brick lining.
- iv. Asphaltic concrete lining
- v. Boulder lining

(b) Earth type

- i. Compacted earth lining
- ii. Soil cement lining

05. Ans: (c) & (d)

Sol:

Q	Free board in m
$Q > 10\ m^3/s$	0.75
$5 < Q < 10\ m^3/s$	0.60
$1 \le Q \le 5\ m^3/s$	0.50
$Q < 1$	0.30
$Q < 0.06$	0.1 to 0.15

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: $P = 4.75\sqrt{Q}$

$P \propto \sqrt{Q}$

$P_1 = \sqrt{Q}$

$P_2 = \sqrt{1.96Q}$

% increase in wetted perimeter

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

04. Ans: (b)

Sol: Lacey's regime scour 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: Perimeter = $b + d\sqrt{5}$

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

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

$27.59 = 4.75\sqrt{Q}$

$\sqrt{Q} = 5.80$

$Q = 33.64$

Practice Solutions

05. Ans: (b)

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

$f = 2$

Lacey's regime scour depth = R_L

$$= 1.35\left(\frac{q^2}{f}\right)^{1/3} = 1.35\left(\frac{4^2}{2}\right)^{1/3} = 2.7\ m$$

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: (b)

Sol: $V_o = ?$

$D = 1.5\ m$

$m = 1.1$

$N = 0.018$

$V_o = 0.55\ mD^{0.64}$

$= 0.55 \times 1.1 \times (1.5)^{0.64}$

$V_o = 0.7843\ m/s$

08. Ans: (a)

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

$= 8 + 2\sqrt{5} = 12.47$

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

$12.47 = 4.75\sqrt{Q}$

$Q = 6.89$

11. Ans: (a), (b) & (d)

Sol: Weep holes, drainage pipes and small humps on canal bed are adopted to counteract the uplift pressure on canal lining.

12. Ans: (a) & (d)

Sol: Silt factor $f = 1.76\sqrt{d_{mm}}$

The channel which has coarser particle, will have large silt factor as compared to other.

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

As Q is same for both channel

$S \alpha f^{5/3}$

Channel A has large silt factor hence slope of channel A will also be large that is steep.

Hydraulic mean depth $R = \frac{5}{2}\frac{V^L}{f}$

$$R \alpha \frac{1}{f}$$

A has large F as compared B

So hydraulic depth of A is less than B, hence B is deeper.

13. Ans: (a) & (b)

Sol: Lacey's regime formula is not applicable to regime channel with sediment concentration more than 500 ppm and lacey's theory is applicable to unlined canal only.

07. Canal 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: $S = \dfrac{\frac{dq}{q}\times 100}{\frac{dD}{D}\times 100}$

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

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

Practice Solutions

04. Ans: (c)

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

Type II Siphon (or) canal siphon

05. Ans: (c), (d)

Sol: A level crossing consist of

(a) A crest with its top at the F.S.L of the canal across the drain at its v/s function with the canal.

(b) A regulator with quick falling across the drain at its d/s junction with canal

(c) Cross regulator across canal at its d/s junction with drain.

Canal escape: It serve as a safety value in entire canal system.

06. Ans: (a), (b) & (c)

Sol: Canal cross – regulator consist of

i. Flash board

ii. Needle regulation

iii. Vertical lift gates

08. 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

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

At mid point

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

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

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

$= 4 - 1.64$ 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

$$t_{\text{min bottom}} = \frac{h}{s_c} = \frac{5}{2.5} = 2 \text{ m}$$

17. Ans: (b)

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

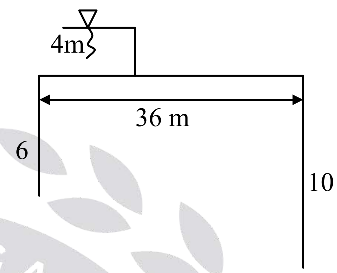
$$= \frac{4}{3} \times \frac{h}{s-1}$$

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

Practice Solutions

02. Ans: (a)

Sol:



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

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

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

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

03. Ans: (a) & (b)

Sol: During normal flow, meander ratio = 1 – 1.5

During flood, meander ratio = 3

04. Ans: (b) & (d)

Sol: When seepage takes place below horizontal floor without any sheet pile, the stream lines are confocal elipses, and equipotential lines are confocal hydperbolas.

05. Ans: (a), (c) & (d)

Sol: The discharge capacity of scouring sluice in head work should be capable of passing at least double the canal discharge 10 – 15% of maximum flood discharge and winter freshest and low flood.

06. Ans: (a) & (c)

Sol: looseness factor $= \frac{\text{Actual width}}{\text{Regime width}}$

Regime width (w) $= 4.75\sqrt{Q}$

$$w = 4.75 \times \sqrt{7000}$$

$$w = 397.41 \text{ m} \simeq 400 \text{ m}$$

looseness factor $= \frac{358}{397.41} = 0.90$

Regime width is also known as wetted perimeter.

9. Gravity Dams

Conceptual Solutions

09. Ans: (d)

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

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

$$= 0.032 \times \sqrt{160 \times 4} = 2.56 \text{ m}$$

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

11. Ans: (c)

Sol: Wave height

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

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

$= 1.62$ m

Free board generally provided equal to

$1.5\ h_w = 1.5 \times 1.62 = 2.45 \text{ m} \approx 2.5$ m

14. 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

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

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

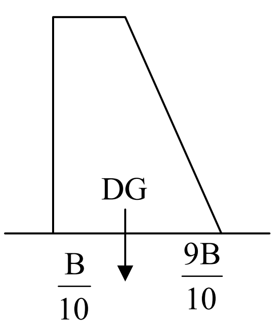
Limiting height at low dam with our considering uplift $H_S = \frac{f}{w(s-G+1)}$

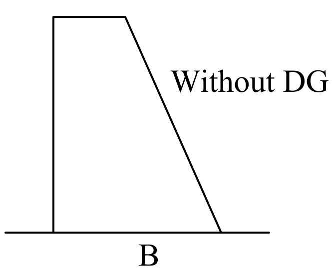
$$= \frac{f}{w(2.5-1+1)} = \frac{f}{w(2.5)}$$

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

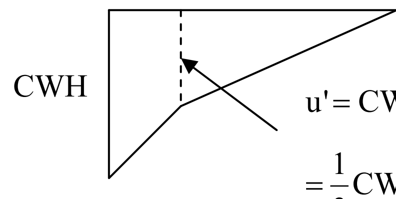
06. Ans: (d)

Sol:





(i) With drainage gallery



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

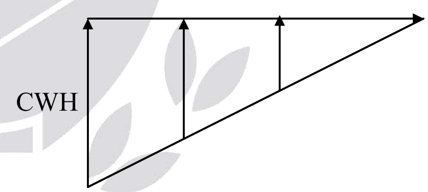
$$U_1 = \frac{B}{10(2)}\left[CWH + \frac{1}{3}CWH\right] + \frac{9B}{10(2)}\frac{CWH}{3}$$

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

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

(ii) 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

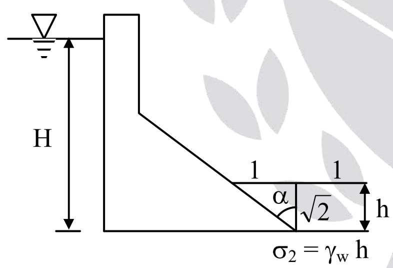
$b = 70$ m

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

SFF = 2.44

08. Ans: (b), (c) & (d)

Sol:



$\tan\alpha = \frac{1}{\sqrt{2}}$

i. $\Sigma V = 0$

$\sigma_1 = \sigma_v \sec^2\alpha - \sigma_2 \tan^2\alpha$

$\sigma_1 = \sigma_v \sec_2 \alpha$

When h = 0 $[\sigma_2 = 0]$

ii. $\Sigma H = 0$

$\tau = (\sigma_v - \sigma_2)\tan\alpha$

$\tau = \sigma_v \tan\alpha$

$\text{Sec}^2\alpha - \tan^2\alpha = 1$

$\text{Sec}^2\alpha = 1 + \tan^2\alpha = 1 + \left(\frac{1}{\sqrt{2}}\right)^2$

$= 1 + \frac{1}{2} = 1.5$

$\sigma_1 = 2 \times 1.5 = 3$ MPa

$\tau = Q \times \frac{1}{\sqrt{2}} = \sqrt{2} = 1.414 \text{ MPa} = 1414 \text{ kPa}$

Shear stress at heel = 0

09. Ans: (a), (b), (c) & (d)

Sol: wave pressure intensity $p_w = 2.4\,\gamma_w\,h_w$

$p_w = 2.4 \times 9.81 \times 1.2 = 28.25 \simeq 29$ kPa

wave pressure force $= 2 \times \gamma_w\ h_w^2$

$= 2 \times 9.81 \times 1.2^2 = 28.25 > 29$ kPa

10. Ans: (b), (c) & (d)

Sol: In mass concreting work, low heat Portland cement is used, not rapid hardening. Rapid hardening cement produce large shrinkage to avoid shrinkage in mass concreting work we need to cool the aggregate etc.

10. 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: (c)

Sol: Net length, L = length of the spillway – 2 × width of piers

= 10 – 2 (0.25)

= 9.5 m

Effective length, $L_e = L - 0.1\ n\ H$

Where n = number of end contractions

$L_e = 9.5 - 0.1 \times 6 \times 0.6$

= 9.5 – 0.36

= 9.14

Practice Solutions

01. Ans: (a), (c) & (d)

Sol: Component:

i. An overflow control weir.

ii. A vertical transition.

iii. A closed discharge channel.

iv. Radial piers

v. Bridge around spillway

iv. Tunnel

02. Ans: (c) & (d)

Sol: If head of water is more than head of design head then cavitations will occur.

If head of water over spillway is less than the designed head, the falling jet would adhere to crest of Ogee spillway creating positive hydrostatic pressure and there by reducing c_d.