DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 24

Full Syllabus Test 8 : Paper-II

1. (d)	23. (d)	45. (d)	67. (b)	89. (c)	111. (c)	133. (c)
2. (d)	24. (a)	46. (a)	68. (c)	90. (d)	112. (d)	134. (b)
3. (a)	25. (d)	47. (a)	69. (a)	91. (d)	113. (b)	135. (d)
4. (d)	26. (b)	48. (c)	70. (d)	92. (b)	114. (c)	136. (c)
5. (c)	27. (d)	49. (d)	71. (c)	93. (b)	115. (a)	137. (a, c)*
6. (c)	28. (b)	50. (b)	72. (b)	94. (a)	116. (b)	138. (c)
7. (b)	29. (d)	51. (c)*	73. (c)	95. (c)	117. (b)	139. (d)
8. (a)	30. (a)	52. (c)	74. (c)	96. (b)	118. (c)	140. (a)
9. (b)	31. (a)	53. (d)	75. (c)	97. (c)	119. (a)	141. (d)
10. (b)	32. (d)	54. (d)	76. (c)	98. (d)	120. (c)	142. (b)
11. (a)	33. (a)	55. (d)	77. (d)	99. (b)	121. (c)	143. (c)
12. (b)	34. (c)	56. (d)	78. (b)	100. (a)	122. (a)	144. (b)
13. (c)	35. (d)	57. (b)	79. (c)	101. (b)	123. (d)	145. (d)
14. (c)	36. (b)	58. (d)	80. (c)	102. (c)	124. (c)	146. (d)
15. (c)	37. (c)	59. (c)	81. (b)	103. (d)	125. (a)	147. (b)
16. (b)	38. (c)	60. (b)	82. (d)	104. (b)	126. (c)	148. (d)
17. (c)	39. (b)	61. (c)	83. (d)	105. (d)	127. (c)	149. (a)
18. (c)	40. (d)	62. (d)	84. (c)	106. (a)	128. (d)	150. (b)
19. (b)	41. (b)	63. (b)	85. (d)	107. (a)	129. (d)	
20. (d)	42. (b)	64. (c)*	86. (a)	108. (a)	130. (a)	
21. (c)	43. (b)	65. (a)	87. (b)	109. (d)	131. (c)	
22. (b)	44. (b)	66. (a)	88. (d)	110. (a)	132. (a)	

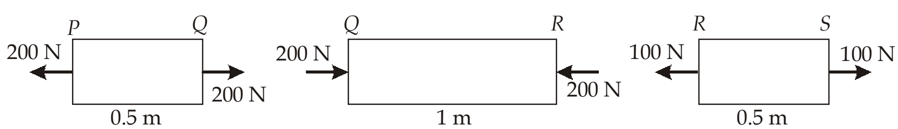
** Answer Key has been changed for Q. No. 51, 64 and 137*

DETAILED EXPLANATIONS

1. (d)

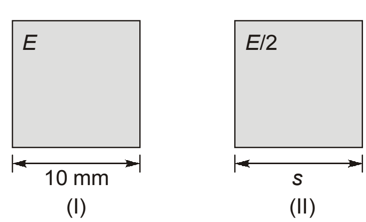
Given,
$$G = 60 \text{ GPa}$$
$$K = 140 \text{ GPa}$$
$$E = 2G(1 + \nu) = 3K(1 - 2\nu)$$
$$\therefore \quad 2G(1 + \nu) = 3K(1 - 2\nu)$$
$$\Rightarrow \quad 2 \times 60(1 + \nu) = 3 \times 140(1 - 2\nu)$$
$$\Rightarrow \quad 120 + 120\nu = 420 - 840\nu$$
$$\Rightarrow \quad (120 + 840)\nu = 300$$
$$\Rightarrow \quad \nu = \frac{300}{960} = 0.3125$$
$$\therefore \quad E = 2G(1 + \mu) = 2 \times 60(1 + 0.3125)$$
$$= 157.5 \text{ GPa}$$

2. (d)



$$\Delta = \Delta_{PQ} + \Delta_{QR} + \Delta_{RS}$$
$$= \frac{F_{PQ}L_{PQ}}{AE} + \frac{F_{QR}L_{QR}}{AE} + \frac{F_{RS}L_{RS}}{AE}$$
$$= \frac{1}{AE}[(200 \times 0.5) + (-200 \times 1) + (100 \times 0.5)]$$
$$= \frac{100 - 200 + 50}{10 \times 10^{-6} \times 200 \times 10^{9}} = -25 \times 10^{-6} \text{ m}$$
$$= -25 \ \mu\text{m}$$

3. (a)



$$\delta_I = \delta_{II}$$
$$\Rightarrow \left(\frac{PL}{AE}\right)_I = \left(\frac{PL}{AE}\right)_{II}$$
$$\Rightarrow \quad A_I E_I = A_{II} E_{II}$$

$$\Rightarrow \quad A_{II} = \frac{E_I}{E_{II}} \cdot A_I = 2 \times 10 \times 10 = 200 \text{ mm}^2$$

$$\Rightarrow \quad s^2 = 200 \text{ mm}^2$$

$$\Rightarrow \quad s = 14.14 \text{ mm} \simeq 14 \text{ mm (say)}$$

4. (d)

Max strain energy per unit volume of material upto elastic limit is called as modulus of resilence.

5. (c)

Since the load is just beyond the proportionality limit therefore total strain can be recovered.

$$\therefore \quad \in = \frac{\sigma}{E} = \frac{50000}{\frac{\pi}{4}(0.01)^2 \times 200 \times 10^9}$$

$$= \mathbf{3.18 \times 10^{-3}}$$

6. (c)

Let, σ_1 and σ_2 are principal stresses

$$\therefore \quad \text{Maximum shear stress} = \frac{\sigma_1 - \sigma_2}{2} = 12 \text{ MPa}$$

$$\therefore \quad \text{Diameter of Mohr circle} = \sigma_1 - \sigma_2 = 24 \text{ MPa}$$

$$\Rightarrow \quad \text{Radius of Mohr's circle} = \frac{24}{2} = 12 \text{ MPa}$$

7. (b)

$$\varepsilon_1 = 0.0004$$

$$\varepsilon_2 = -0.00012; \ \mu = 0.3$$

$$E = 2 \times 10^5 \text{ MPa}$$

$$\sigma_1 = \frac{E}{(1-\mu^2)}(\varepsilon_1 + \mu\varepsilon_2)$$

$$\Rightarrow \quad \sigma_1 = \frac{2 \times 10^5}{1-0.09}[0.0004 + (0.3 \times -0.00012)]$$

$$\Rightarrow \quad \sigma_1 = 80 \text{ MPa}$$

$$\sigma_2 = \frac{E}{(1-\mu^2)}(\varepsilon_2 + \mu\varepsilon_1)$$

$$= \frac{2 \times 10^5}{1-0.09}(-0.00012 + 0.3 \times 0.0004)$$

$$\Rightarrow \quad \sigma_2 = 0$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{80-0}{2} = \mathbf{40 \text{ MPa}}$$

8. (a)

For plastic deformation

$$\mu = 0.5$$

Principal strain

$$\in_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E} - \frac{\mu\sigma_3}{E}$$

$$= \frac{30 - (0.5 \times 10) - (0.5 \times 5)}{E} = \frac{22.5}{E}$$

$$\in_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_3}{E}$$

$$= \frac{10 - (0.5 \times 30) - (0.5 \times 5)}{E}$$

$$\in_2 = \frac{-7.5}{E}$$

and $$\in_3 = \frac{\sigma_3}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_2}{E}$$

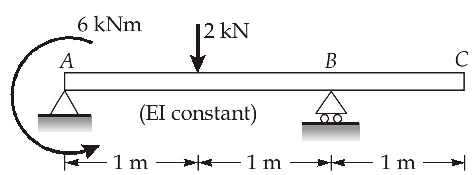
$$= \frac{5 - (0.5 \times 30) - (0.5 \times 10)}{E}$$

$$= \frac{-15}{E}$$

$$\therefore \in_1 : \in_2 : \in_3 = 22.5 : -7.5 : -15$$

$$= 15 : -5 : -10 = 3 : -1 : -2$$

9. (b)



Rotation at B due to moment at A = $\frac{ML}{6EI}$

Rotation at B due to moment at A = $\frac{6 \times 2}{6EI} = \frac{2}{EI}$

Rotation at B due to load at mid point = $-\frac{PL^2}{16EI}$

$$= -\frac{2 \times 2^2}{16EI}$$

$$= -\frac{1}{2EI}$$

Net rotation at B = $\frac{2}{EI} - \frac{1}{2EI} = \frac{3}{2EI}$

Deflection at C = $\theta \times L'$

$$= \frac{3}{2EI} \times 1 = \frac{3}{2EI}$$

10. (b)

For first case i.e. case (A)

$$I_A = \frac{1}{12} \times b \times \left(\frac{b}{2}\right)^3 = \frac{b^4}{12 \times 8}$$

$$\frac{M}{I_A} = \frac{\sigma_A}{y} \Rightarrow \frac{M \times 12 \times 8}{b^4} = \frac{\sigma_A}{b/4}$$

$$\Rightarrow \sigma_A = \frac{24M}{b^3}$$

For second case i.e. case (B)

$$I_B = \frac{1}{12} \times \left(\frac{b}{2}\right) \times (b)^3 = \frac{b^4}{12 \times 2}$$

$$\therefore \frac{M}{I_B} = \frac{\sigma_B}{y}$$

$$\Rightarrow \frac{M}{\frac{b^4}{12 \times 2}} = \frac{\sigma_B}{\frac{b}{2}}$$

$$\therefore \sigma_B = \frac{12M}{b^3}$$

$$\therefore \sigma_A = 2\sigma_B$$

11. (a)

Stress in hollow shaft ,

$$\sigma_H = \frac{16 d_0 M_1}{\pi\left(d_0^4 - d_1^4\right)}$$

$$= \frac{16 d_0 M_1}{\pi\left(d_0^4 - \left(\frac{d_0}{2}\right)^4\right)} = \frac{16 M_1}{\frac{15}{16}\pi d_0^3}$$

Stress in solid shaft, $\sigma_S = \dfrac{16 M_2}{\pi d_0^3}$

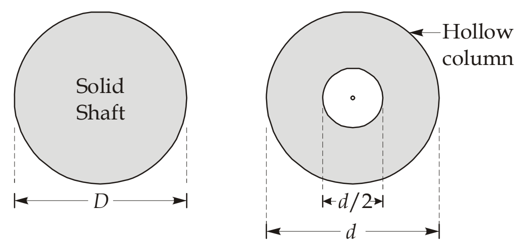
$\therefore$ Material is same.

$$\therefore \sigma_H = \sigma_S$$

Now $\dfrac{16 \times 16 M_1}{15 \pi d_0^3} = \dfrac{16 M_2}{\pi d_0^3}$

$$\therefore \qquad \frac{M_1}{M_2} = \frac{15}{16}$$

12. (b)



$$A_s = A_h$$

$$\Rightarrow \quad \frac{\pi}{4}D^2 = \frac{\pi}{4}\left[d^2 - \left(\frac{d}{2}\right)^2\right]$$

$$\Rightarrow \quad D^2 = \frac{3d^2}{4};$$

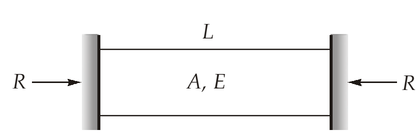
$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

$$\therefore \quad \frac{P_s}{P_h} = \frac{I_s}{I_h} = \frac{\pi D^4}{64} \times \frac{64}{\pi\left[d^4 - \left(\frac{d}{2}\right)^4\right]}$$

$$= \frac{16D^4}{15d^4}$$

$$\therefore \quad \frac{P_s}{P_h} = \frac{16}{15}\left(\frac{D^2}{d^2}\right)^2 = \frac{16}{15} \times \frac{9}{16} = \frac{9}{15} = \frac{3}{5}$$

13. (c)



$$\Delta_{act} = 0$$

Expansion in rod due to temperature rise = Contraction in rod due to compressive reaction force.

$$\Rightarrow \quad L\alpha \,.\, \Delta T = \frac{RL}{AE}$$

$$\Rightarrow \quad R = \alpha . \Delta T . AE$$

$$= 10 \times 10^{-6} \times 50 \times 20 \times 10^{-4} \times 200 \times 10^9$$

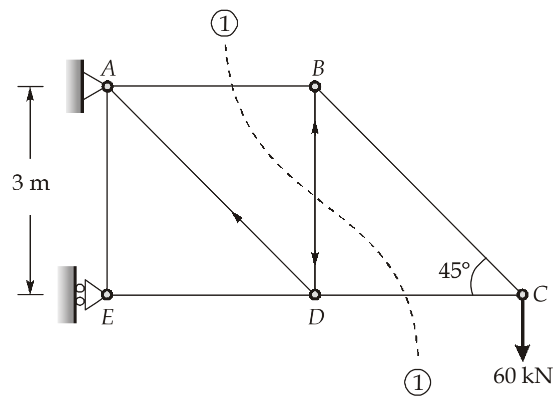
$$= 200 \times 10^3 \text{ N} = \mathbf{200 \text{ kN}}$$

14. (c)

Bottom end behaves as a fixed support and upper end is hinged so effective length = $L/\sqrt{2}$

$$\therefore \qquad P_{cr} = \frac{2\pi^2 EI}{L^2}$$

17. (c)



Cut section (1)-(1)

For right portion of truss, $\Sigma F_y = 0$

$$\Rightarrow \qquad F_{BD} = 60 \text{ kN (Compression)}$$

At joint D

$$\Sigma F_y = 0$$

$$\Rightarrow \qquad F_{AD} \times \cos 45° - 60 = 0$$

$$\Rightarrow \qquad F_{AD} = 60\sqrt{2} \text{ kN (Tension)}$$

18. (c)

$$\because \qquad [\Delta]_{\text{final}} = [\Delta] + [\delta][P]$$

$$\Rightarrow \qquad \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -\Delta / EI \\ 0 \end{bmatrix} + \frac{1}{3EI}\begin{bmatrix} 1 & 4 \\ 4 & 8 \end{bmatrix}\begin{bmatrix} V_B \\ V_C \end{bmatrix}$$

$$\Rightarrow \qquad \frac{3EI}{-8}\begin{bmatrix} 8 & -4 \\ -4 & 1 \end{bmatrix}\begin{bmatrix} \Delta / EI \\ 0 \end{bmatrix} = \begin{bmatrix} V_B \\ V_C \end{bmatrix}$$

$$\frac{-3EI}{8} \times \frac{8\Delta}{EI} = V_B$$

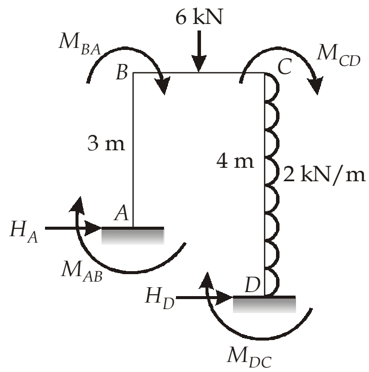
$$\Rightarrow \qquad V_B = -3\Delta$$

and

$$\frac{-3EI}{8} \times \left(\frac{-4\Delta}{EI}\right) = V_C$$

$$V_C = 1.5\Delta$$

20. (d)

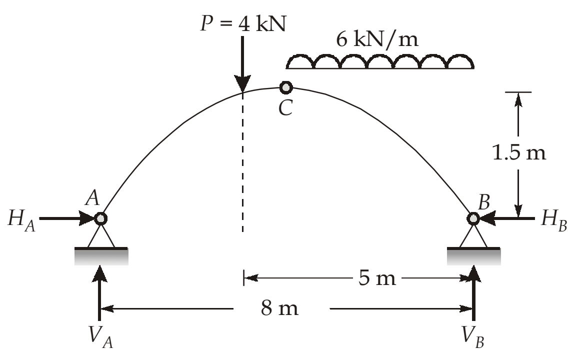


Shear equation, $H_A + H_D - w.L_2 = 0$

$$\frac{M_{BA}+M_{AB}}{3}+\frac{M_{CD}+M_{DC}+\frac{2\times 4^2}{2}}{4}-2\times 4=0$$

$$\frac{M_{BA}+M_{AB}}{3}+\frac{M_{CD}+M_{DC}}{4}-4 = 0$$

22. (b)



$$\Sigma M_B = 0$$

$\Rightarrow$ $V_A \times 8 - 4 \times 5 - 6 \times 4 \times 2 = 0$

$$V_A = 8.5 \text{ kN}$$

$\Sigma M_C = 0$ of left part of arch

$\Rightarrow$ $V_A \times 4 - H_A \times 1.5 - 4 \times 1 = 0$

$\Rightarrow$ $8.5 \times 4 - H_A \times 1.5 - 4 = 0$

$\Rightarrow$ $H_A = 20 \text{ kN} \quad (= H_B)$

23. (d)

Damped circular frequency, $w_D = w_n\sqrt{1-\epsilon^2}$

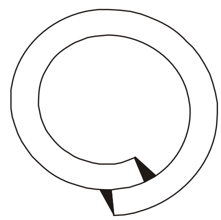
$$= \sqrt{\frac{k}{m}} \times \sqrt{1-0.02^2}$$

$$= \sqrt{\frac{15 \times 10^3}{20}} \times \sqrt{1 - 0.02^2}$$
$$= 27.38 \text{ Hz} \simeq 27.4 \text{ Hz}$$

26. (b)

In some cases a seat angle will not be strong enough to support the heavy load and within the size of angle it may not be possible to accomodate the needed number of bolts. In such a case, stiffened seat connection is provided.

28. (b)



Throat thickness of weld, $t_t = 0.7s = 0.7 \times 8 = 5.6$ mm

Design stress for weld, $f_{wd} = \dfrac{410}{\sqrt{3} \times 1.25} = 189.4 \text{ N/mm}^2$

Design strength of weld per mm length of the cylinder

$= 2(189.4 \times 1 \times 5.6)$

$= 2121.28$ N/mm

Let p_d = Design fluid pressure inside the cylinder

Design hoop tension per mm length of cylinder = $p_d \cdot \dfrac{D}{2} = p_d \times \dfrac{500}{2} = 2121.28$

$p_d = 8.48 \text{ N/mm}^2$

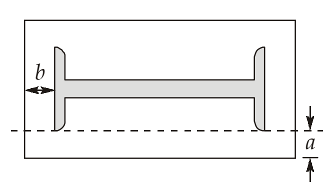
30. (a)

Bearing stress on the base plate, $w = \dfrac{1200 \times 10^3}{400 \times 400} = 7.5 \text{ N/mm}^2 < 0.45 f_{ck} = 0.45 \times 25 = 11.25 \text{ N/mm}^2$

Overall depth of the column section = 300 mm

Flange width = 250 mm

Projection of the base plate beyond the overall dimensions of the column are,



$$b = \frac{400 - 300}{2} = 50 \text{ mm}$$

and $$a = \frac{400-250}{2} = 75 \text{ mm}$$

$$\text{Thickness of base plate, } t_s = \sqrt{\frac{2.5w\left(a^2 - 0.3b^2\right)}{f_y} \times \gamma_{m0}}$$

$$= \sqrt{\frac{2.5 \times 7.5\left(75^2 - 0.3(50)^2\right)}{250} \times 1.1} = 20 \text{ mm}$$

31. (a)

$$\text{Moment of inertia of the section, } I = \frac{90(120)^3}{12} - \frac{\pi}{64}(60)^4 = 12323827.49 \text{ mm}^4$$

$$\text{Section modulus of the section, } z = \frac{I}{y_{\max}} = \frac{12323827.49}{60} = 205397.12 \text{ mm}^3$$

$$\text{Plastic modulus of section, } z_p = 2\left[90 \times 60 \times 30 - \frac{\pi(30)^2}{2} \times \frac{4 \times 30}{3\pi}\right] = 288000 \text{ mm}^3$$

$$\therefore \quad \text{Shape factor} = \frac{z_p}{z} = \frac{288000}{205397.12} = 1.4$$

33. (a)

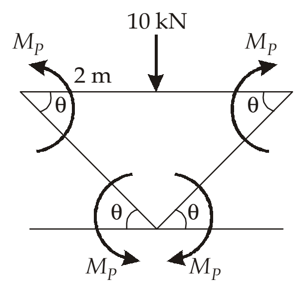
$$n = 6 - 3 = 3$$

Possible number of locations for formation of plastic hinges = 5 (A, B, E, C, D)

∴ Number of independent mechanisms = 5 – 3 = 2

(i) Beam mechanism

For span BC (plastic hinges at B, E and C)

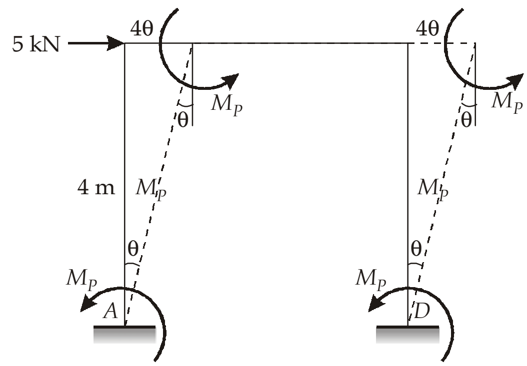


$$M_p\theta + M_p(\theta + \theta) + M_p\theta = 10(2\theta)$$

$$\Rightarrow \quad -4M_p\theta + 10 \times 2\theta = 0$$

$$M_p = 5 \text{ kNm}$$

(ii) Sway mechanism (plastic hinges at A, B, C, D)



$$M_p\theta + M_p\theta + M_p\theta + M_p\theta = 5(4\theta)$$

$\Rightarrow$ $4M_p\theta = 5 \times 4\theta$

$\Rightarrow$ $M_p = 5$ kNm

Thus, $M_p = 5$ kNm

36. (b)

$$b = 250 \text{ mm}, d = 500 \text{ mm}$$

$$A_{st} = 4 \times \frac{\pi}{4} \times 16^2 = 4 \times 201 = 804 \text{ mm}^2$$

$$f_{ck} = 20 \text{ N/mm}^2, f_y = 250 \text{ N/mm}^2$$

Equating compressive and tensile forces,

$$C = T$$

$\Rightarrow$ $0.36 f_{ck}\, bx_u = 0.87\, f_y A_{st}$

$\Rightarrow$ $0.36 \times 20 \times 250 \times x_u = 0.87 \times 250 \times 804$

$$x_u = \frac{0.87 \times 250 \times 804}{0.36 \times 20 \times 250} = 97.15 \text{ mm}$$

For $x_{u,\text{lim}} = 0.53d = 0.53 \times 500 = 265$ mm $\quad x_u < x_{u,lim} \quad$ (OK)

$\therefore$ Section is under-reinforced, $x_u = 97.15 \text{ mm} \simeq 97$ mm

37. (c)

$B = 1000$ mm, $D_f = 100$, $D_w = 250$ mm, $d = 500$ mm

$A_{st} = 1500 \text{ mm}^2$, $f_{ck} = 25 \text{ N/mm}^2$, $f_y = 250 \text{ N/mm}^2$

Assuming neutral axis to lie within the flange and equating the compression and tension,

$$0.36\, f_{ck} B x_u = 0.87 f_y A_{st}$$

$\Rightarrow$ $x_u = \dfrac{0.87 \times 250 \times 1500}{0.36 \times 25 \times 1000} = 36.25 \text{ mm} \quad (< D_f = 100 \text{ mm})$ OK

Hence our assumption is correct.

$x_{u,\max} = 0.53d = 0.53 \times 500 = 265$ mm $\quad \therefore x_u < x_{u,\max}$

$\therefore$ Ultimate MOR $= 0.87\, f_y A_{st} (d - 0.42\, x_u)$

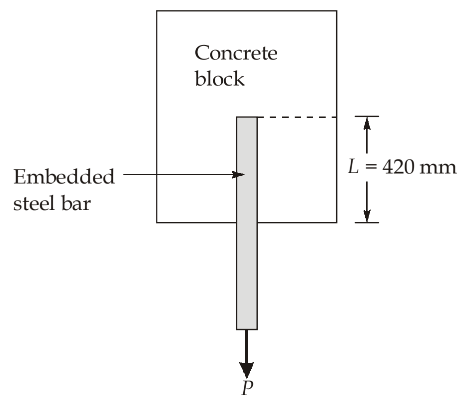
$= 0.87 \times 250 \times 1500 \times (500 - 0.42 \times 36.25)$ N.mm

$= 158.16$ kNm

38. (c)

A standard 90° bend has an anchorage value 8ϕ, including a minimum extension of 4ϕ. The minimum turning radius (internal) specified for a hook is 2ϕ for plain mild steel bars and 4ϕ for cold worked deformed bars.

39. (b)



$$\text{Diameter of bar } (\phi) = 12 \text{ mm}$$

$$\tau_{bd} = 1.25 \text{ N/mm}^2 \quad \text{[Fe250]}$$

Maximum force resisted by bond strength,

$$F_1 = \tau_{bd} \times (\pi \phi L)$$

$$= 1.25 \times \pi \times 12 \times 420 = 19.79 \text{ kN} \simeq 19.8 \text{ kN}$$

Maximum tensile force resisted by bar,

$$F_2 = \sigma_{st}\left(\frac{\pi}{4}\phi^2\right)$$

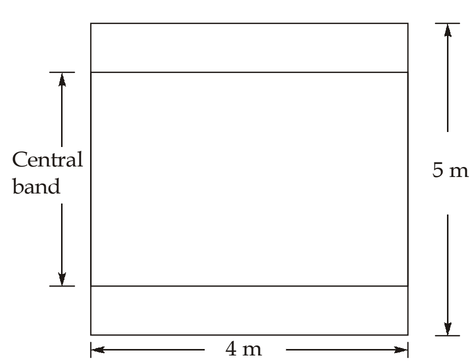
$$= 0.87 \times 250\left(\frac{\pi}{4} \times (12)^2\right)$$

$$= 24.6 \text{ kN}$$

∴ Maximum value of P = Minimum – (F_1, F_2)

= Minimum {19.8 kN, 24.6 kN} = 19.8 kN

40. (d)

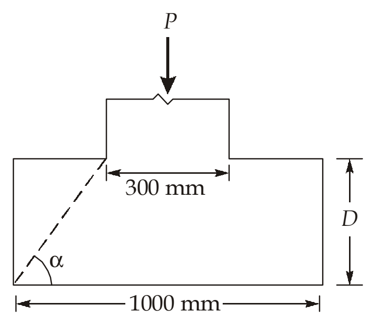


$$\text{Central band reinforcement} = \left(\frac{2}{\beta+1}\right) \times \text{Total reinforcement in shorter direction}$$

$$= \left(\frac{2}{\frac{5}{4}+1}\right) \times 18 = \frac{8}{9} \times 18$$

= 16 number of bars

41. (b)



$$\text{Thickness of footing, } D = \left(\frac{1000-300}{2}\right)\tan\alpha = 350\tan\alpha$$

where, $\tan\alpha \geq 0.9\sqrt{\frac{100 q_{\max}}{f_{ck}} + 1}$

Given, $q_{\max} = 360 \text{ kN/m}^2 = 0.360 \text{ N/mm}^2$

$f_{ck} = 20 \text{ N/mm}^2$

∴ $\tan\alpha \geq 0.9\sqrt{\frac{100 \times 0.36}{20} + 1}$

∴ $D = 350 \times 0.9\sqrt{\frac{100 \times 0.36}{20} + 1}$

⇒ $D \geq 527 \text{ mm}$

42. (b)

The effective width

$$b = 3\left(\frac{t}{2} - e\right) \qquad \therefore \frac{1}{2}\sigma_c b = p$$

⇒ $$\sigma_c = \frac{2p}{b} = \frac{2p}{3\left\{\left(\frac{t}{2}\right) - e\right\}}$$

43. (b)

$$\text{Heel slab length, } L = H\sqrt{\frac{k_a}{3}}$$

where H is the height of the retaining wall

$$\Rightarrow \quad L = 5.5 \times \sqrt{\frac{k_a}{3}}$$

where,
$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30^\circ}{1+\sin 30^\circ} = \frac{1}{3}$$

$$L = 5.5 \times \sqrt{\frac{1}{9}} = \frac{5.5}{3}$$
$$= 1.833 \text{ m}$$

46. (a)

$$\text{Area of beam section} = 150 \times 300 = 45 \times 10^3 \text{ mm}^2$$

$$\text{Section modulus, } Z = \frac{Bd^2}{6} = \frac{150 \times 300^2}{6} = 2.25 \times 10^6 \text{ mm}^3$$

$$\text{Dead load} = 0.15 \times 0.30 \times 1 \times 25 = 1.125 \text{ kN/m}$$

For bottom fibre stress to be zero

$$\frac{P}{A} + \frac{Pe}{Z} = \frac{M_{DL} + M_{LL}}{Z}$$

$$M_{DL} + M_{LL} = \frac{(1.125 + 3.875) \times 8^2}{8} = 40 \text{ kN-m}$$

$$e = 81 \text{ mm}$$

$$\therefore \quad P = \frac{40 \times 10^6}{2.25 \times 10^6 \left[\frac{1}{45 \times 10^3} + \frac{81}{2.25 \times 10^6}\right]} \text{N}$$

$$= 305.34 \text{ kN}$$

47. (a)

In *ABC* analysis, the items are classified in three main categories based on their respective usage value:

Category '*A*' items : Most costly & valuable items.

Category '*B*' items: These items are having average consumption value.

Category '*C*' items: These items are having low consumption value.

48. (c)

$$C_{F_1} + C_{v_1} x = C_{F_2} + C_{v_2} x$$

$$\Rightarrow \quad 40000 + 9x = 16000 + 24x$$

$$\Rightarrow \quad 24000 = 15x$$

$$\Rightarrow \qquad x = \frac{24000}{15} = 1600$$

49. (d)

$$\text{Break even point (BEP)} = \frac{\text{Fixed cost}}{\text{Revenue per unit} - \text{Variable cost per unit}}$$

$$= \frac{50000}{15-10}$$

$$= 10000$$

50. (b)

Rules for drawing network diagram:

(i) Each activity is represented by one and only one arrow in the network.

(ii) No two activities can be identified by the same beginning and end events.

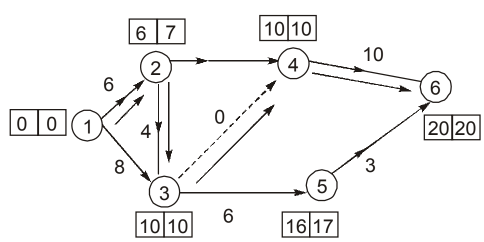
(iii) In order to ensure the correct precedence relationship in the arrow diagram, following question must be checked whenever any activity is added to network:

(a) What activity must be completed immediately before this activity can start?

(b) What activity must follow this activity?

(c) What activity must occur simultaneously with this activity?

54. (d)



$\because \qquad \text{Variance} = 4$

$$\sigma = \sqrt{Var} = \sqrt{4} = 2$$

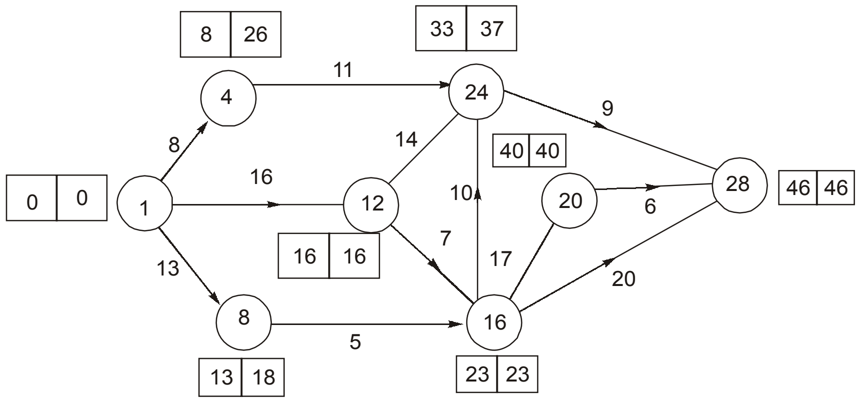
$$Z = \frac{T_S - T_E}{\sigma} = \frac{24-20}{2} = 2$$

We know that

$$P(Z = -2) + P(Z = 2) = 1.0$$

$$\therefore \qquad P(Z = 2) = 1 - 0.023 = 0.977$$

55. (d)



$\therefore$ Earliest time of completion = **46 weeks**

57. (b)

Sand streaks occur due to excessive bleeding.

61. (c)

Stone work is more water tight than brick work.

64. (c)

As per IS 1077, minimum crushing strength for common building bricks should be 35 kg/cm^2. With mortar, thickness of modular brick becomes 20 cm x 10 cm x 10 cm. Actual size of modular brick is 19 cm x 9 cm x 9 cm.

66. (a)

In dry rot, fungi attack on wood and convert it into dry powder form. Other defects in timber due to fungus attack are: Blue stain, Brown rot, Heart rot, Sap stain, Wet rot.

Alternate wetting and drying of timber favour the development of wet rot in which the fungi converts timber into greyish powder form.

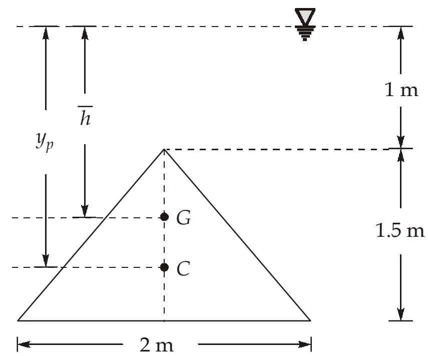
67. (b)

Finer the cement, more is the rate of hydration which results in development of early strength. Burning at higher temperature increases tricalcium sulphate (C_3S) and hence leads to high early strength.

68. (c)

Asbestos cement has low heat conductivity.

69. (a)



$$\text{Total pressure force, } F = \gamma A \bar{h}$$

$$= 9.81 \times \left(\frac{1}{2} \times 2 \times 1.5\right) \times \left(1 + \frac{2}{3} \times 1.5\right)$$

$$= 29.43 \text{ kN}$$

$$\text{Center of pressure, } y_p = \bar{h} + \frac{I_{CG} \sin^2 \theta}{A.\bar{h}}$$

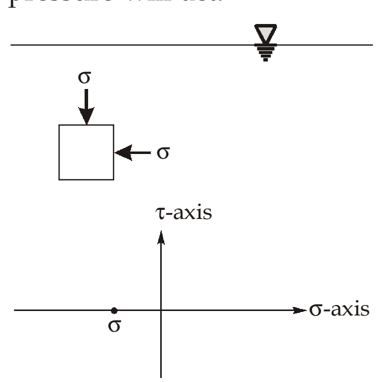
$$\bar{h} = 1 + \frac{2}{3} \times 1.5 = 2 \text{ m}$$

$$I_{C.G} = \frac{bh^3}{36} = \frac{2 \times 1.5^3}{36} \text{ m}^4, \quad \theta = 90°$$

$$\therefore \quad y_p = 2 + \frac{2 \times 1.5^3}{36 \times \frac{1}{2} \times 2 \times 1.5 \times 2} = 2.0625 \text{ m} \simeq 2.1 \text{ m}$$

70. (d)

Inside a fluid only hydrostatic pressure will act.



71. (c)

For flow to be possible, continuity equation should be satisfied.

$$\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$$

$$\Rightarrow \quad a_1 + b_2 = 0$$

$$\Rightarrow \quad a_1 = -b_2$$

Next the irrotational flow condition must be satisfied i.e.

$$\frac{\partial V}{\partial x} = \frac{\partial U}{\partial y}$$

$$\Rightarrow \quad a_2 = b_1$$

72. (b)

$$u = \frac{u_1}{B} \cdot y$$

Consider unit width of the conduit

$$\text{Average velocity } V_{avg} = \frac{u_1}{2}$$

$$\therefore \quad \alpha = \frac{1}{V^3 B}\int_0^B u^3 \cdot dy$$

$$= \frac{1}{\left(\frac{u_1}{2}\right)^3 \cdot B}\int_0^B \left(\frac{u_1 y}{B}\right)^3 \cdot dy$$

$$= \frac{8}{B}\left(\frac{B^4}{4B^3}\right) = 2$$

73. (c)

$$\because \quad F = \rho Q V$$

$$Q = \frac{\pi}{4} d^2 V = 0.0424 \text{ m}^3/\text{s}$$

$$F = 635 \text{ N}$$

$$\Rightarrow \quad 635 = 1000 \times 0.0424 \times V$$

$$\Rightarrow \quad V = 14.98 \text{ m/s} \simeq 15 \text{ m/s}$$

74. (c)

Drag force on a cylinder for laminar flow is more compared to turbulent flow.

75. (c)

$\because$ Thickness of laminar boundary layer over a flate plate $\delta = \dfrac{5x}{\sqrt{Re_x}} = \dfrac{5x}{\sqrt{\dfrac{\rho v x}{\mu}}} = \dfrac{5\sqrt{x}}{\sqrt{\dfrac{\rho v}{\mu}}}$

$$\therefore \quad \delta \propto \sqrt{x}$$

$$\therefore \quad \frac{\delta_P}{\delta_Q} = \sqrt{\frac{x}{4+x}}$$

$$\Rightarrow \quad \frac{0.9}{2.8} = \sqrt{\frac{x}{4+x}}$$

$$\Rightarrow \quad \frac{81}{784} = \frac{x}{4+x}$$

$$\Rightarrow \quad 324 + 81x = 784x$$

$$\Rightarrow \quad x = 0.46 \text{ m}$$

76. (c)

When electrical load changes depending upon the demand, the speed of the turbine changes automatically. This is because external resisting torque on the shaft is altered while the driving torque due to change of momentum in the flow of fluid through the turbine remains the same. For example, when the load is increased, the speed of the turbine decreases and vice versa. A constancy in speed is therefore maintained by adjusting the rate of energy input to the turbine accordingly. This usually is accomplished by changing the rate of fluid flow through the turbine; the flow is increased when the load is increased and the flow is decreased when the load is decreased. This adjustment of flow with the load is known as the governing of turbines.

78. (b)

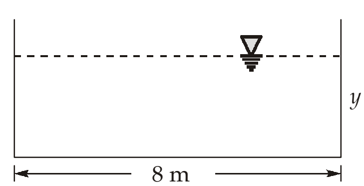
$$\because \quad \text{Specific speed, } N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

$$\Rightarrow \quad 25 = \frac{800 \times \sqrt{0.16}}{H_m^{3/4}}$$

$$\Rightarrow \quad H_m = 29.94 \text{ m}$$

$$\therefore \quad \text{Number of pumps required} = \frac{89}{29.94} \simeq 2.97 \simeq 3$$

79. (c)



$$\because \quad \text{Hydraulic radius, } R = \frac{A}{P}$$

For most efficient rectangular channel,

$$y = \frac{B}{2} = \frac{8}{2} = 4 \text{ m}$$

$\therefore \quad A = By = 8 \times 4 \text{ m}^2$

$P = B + 2y = 8 + 2 \times 4 = 16 \text{ m}$

$\therefore \quad R = \dfrac{8 \times 4}{16} = 2 \text{ m}$

80. (c)

For rectangular channel, $E_c = \dfrac{3}{2} \cdot y_c$

where, $y_c = \left(\dfrac{q^2}{g}\right)^{1/3}$

$q = \dfrac{20}{10} = 2 \text{ m}^3/\text{s/m}$

$\Rightarrow \quad E_c = \dfrac{3}{2}\left(\dfrac{2^2}{9.81}\right)^{1/3} = 1.11 \text{ m}$

81. (b)

$$\text{NPSH} = \text{Cavitation coefficient} \times \text{Manometric head} = 0.1 \times 40 = 4 \text{ m}$$

Now, $\text{NPSH} = \dfrac{P_{atm} - P_v}{\rho g} - h_s - h_{fs}$

Safe height of runner, $h_s + h_{fs} = \dfrac{P_{atm} - P_v}{\rho g} - NPSH$

$= 9 - 1.6 - 4$

$= 3.4 \text{ m}$

82. (d)

When soil is in solid or semi-solid stage, soil behaves like a brittle material.

83. (d)

$$G_s = \frac{w_s}{w_4 - w_3 + w_2 - w_1} = \frac{100}{550 - 613 + 100} = 2.7$$

84. (c)

Shrinkage limit is the maximum water content at which a decrease in moisture content doesnot cause any decrease in the volume of soil mass.

85. (d)

$$\frac{S_{C_1}}{S_{C_2}} = \frac{\log\left(\bar{\sigma}_f / \bar{\sigma}_0\right)_1}{\log\left(\bar{\sigma}_f / \bar{\sigma}_0\right)_2}$$

Since, $$\frac{200}{100} = \frac{400}{200}$$

$$\Rightarrow \quad \log\left(\frac{\bar{\sigma}_t}{\bar{\sigma}_0}\right)_1 = \log\left(\frac{\bar{\sigma}_t}{\bar{\sigma}_0}\right)_2$$

$$\Rightarrow \quad S_{C_1} = S_{C_2} = 10 \text{ mm}$$

86. (a)

% of soil retained on the 75μ sieve = 80, i.e. > 50%.

Hence it is coarsed-grained soil.

Since a larger proportion of the coarse-grained soil is gravel, the soil is gravel.

Since 75μ friction is 20% (> 12%) we need to refer from the plasticity chart.

$$w_L = 35\% \text{ and } I_P = w_L - w_P = 35 - 20 = 15\%$$

Point lies above the A-line

Soil is GC

88. (d)

Taylor's stability number is function of ϕ_u and β(slope angle) only.

89. (c)

$$\tau = \frac{T}{\pi D^2\left(\frac{H}{2}+\frac{D}{6}\right)}$$

$$= \frac{35 \times 1000}{\pi(50)^2\left(\frac{100}{2}+\frac{50}{6}\right)}$$

$$= 0.076 \text{ N/mm}^2$$

$$= 76 \text{ kN/m}^2$$

90. (d)

Active earth pressure is associated with the expansion of the soil and is the minimum lateral earth pressure, while passive pressure is associated with the compression of the soil is maximum lateral pressure.

'At rest' earth pressures exists when the wall-earth system is rigid so that there is no relative motion between the wall and the earth.

92. (b)

For cohesive soil,

$$N_\gamma = 0$$

$$\therefore \quad q_u = cN_c + qN_q$$

which is independent of width of footing (β).

However, total load bearing capacity = $q_u \cdot A$

$$= q_u(B.L.) \text{ which increases with } B.$$

Therefore, the total load bearing capacity is, of course, gets increased when the width of the footing is increased, since there is an increase in the area of the footing. However, bearing capacity will remain unaffected.

93. (b)

$$\text{Equivalent permeability, } k_e = \sqrt[3]{k_x k_y k_z}$$
$$= (2 \times 5 \times 12.5)^{1/3}$$
$$= (125)^{1/3} = 5 \text{ m/s}$$
$$\text{Available head above filter, } H = 30 \text{ m}$$
$$\text{Number of flow channels, } N_f = 6$$
$$\text{Number of potential drops} = 12$$
$$\therefore \text{ Seepage per unit length of dam, } q = k_e \cdot H \cdot \frac{N_f}{N_d}$$
$$= 5 \times 30 \times \frac{6}{12} = 75 \text{ m}^3\text{/s/m or } 75 \times 10^3 \ l\text{/s/m}$$

95. (c)

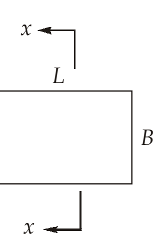
Annual rechargeable ground water storage (m^3)

$$= \text{Area (in m}^2) \times \text{Variation in Piezometric head (in m)} \times \text{Storage coefficient}$$
$$= 900 \times 10^6 \times (12 - 5) \times 0.0004$$
$$= 2.52 \text{ Mm}^3$$

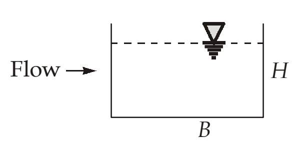
96. (b)

- Nitrite is highly dangerous as it denotes the partly (or partially) oxidised organic matter.
- Nitrite denotes partially oxidised organic matter. Its too much presence causes a disease called methemoglobinemia.
- The presence of total ammonia in water should not exceed 0.5 mg/l. [Refer S.No. (ii), Table 2 of IS:10500:2012]

97. (c)



Plan



Section *x-x*

$$V_s = 0.055 \text{ cm/s}$$
$$Q = V_s \times L \times B$$
$$\text{Flow velocity} = \frac{Q}{B \times H}$$

Here, B = Width of tank, H = Height of tank, L = Length of tank

$$\therefore \quad \text{Flow velocity} = \frac{V_s \times L \times B}{B \times H} = V_s \times \frac{L}{H}$$
$$= 0.055 \times \frac{60}{3} = 1.1 \text{ cm/s}$$

98. (d)

In slow sand filter, effective size (D_{10}) of sand varies from 0.2 to 0.4 mm and uniformity coefficient varies from 1.8 to 2.5 or 3.0 and an rapid sand filter, effective size (D_{10}) of sand varies from 0.35 to 0.55 mm and uniformity coefficient ranges from 1.3 to 1.7.

100. (a)

An inverted siphon runs full under gravity with pressure greater than the atmospheric pressure.

102. (c)

$$\text{Percolation rate} = 240 \text{ seconds} = 4 \text{ minutes}$$

So, maximum rate of effluent application = $\frac{204}{\sqrt{t}}$ where t is in minutes

$$= \frac{204}{\sqrt{4}} = \frac{204}{2} = 102 \; l/\text{m}^2/\text{day}$$

106. (a)

$n = 4$,

$$\bar{P} = \frac{80 + 100 + 120 + 140}{4} = 110 \text{ cm}$$
$$\sigma_{m-1} = \sqrt{\frac{\Sigma\left(P - \bar{P}\right)^2}{n-1}}$$
$$= \sqrt{\frac{(80-110)^2 + (100-110)^2 + (120-110)^2 + (140-110)^2}{3}}$$
$$= \sqrt{\frac{(30)^2 + (10)^2 + (10)^2 + (130)^2}{3}}$$
$$= \sqrt{\frac{900 + 100 + 100 + 900}{3}} = 25.82 \text{ cm}$$
$$C_V = \frac{100 \times \sigma_{m-1}}{\bar{P}} = \frac{100 \times 25.82}{110} = 23.47$$

So, optimum number of rain-gauge stations = $\left(\frac{C_V}{E}\right)^2 = \left(\frac{23.47}{10}\right)^2 = 5.5 \simeq 6\,(\text{say})$

108. (a)

Given k = 12 hr, Δt = 6 hr., x = 0.20

$$c_0 = \frac{-kx + 0.5\Delta t}{k(1-x) + 0.5\Delta t}$$

$$= \frac{-12 \times 0.2 + 0.5 \times 6}{12(1-0.2) + 0.5 \times 6} = \frac{-2.4 + 3}{9.6 + 3} = \frac{0.6}{12.6} = 0.048$$

$$c_1 = \frac{kx + 0.5\Delta t}{k(1-x) + 0.5\Delta t} = \frac{2.4 + 3}{9.6 + 3} = 0.429$$

$$c_2 = \frac{k(1-x) - 0.5\Delta t}{k(1-x) + 0.5\Delta t} = \frac{12(1-0.2) - 0.5 \times 6}{12(1-0.2) + 0.5 \times 6} = 0.523$$

Alternatively,

$$c_2 = 1 - (c_0 + c_1)$$
$$= 1 - (0.048 + 0.429)$$
$$= 0.523$$

109. (d)

Rising limb is dependent on both storm characteristics and catchment characteristics.

110. (a)

Surface runoff is a part of direct runoff. The delayed flow that reaches a stream essentially as ground water flow is called base flow.

111. (c)

$$\text{Risk, } \bar{R} = 1 - \left(1 - \frac{1}{T}\right)^n$$

Here, n = 25 years, and T = 100 years

$$\therefore \quad \bar{R} = 1 - \left(1 - \frac{1}{100}\right)^{25}$$

112. (d)

To safeguard against scouring action, launching aprons are provided both at upstream and downstream end of the floor.

A graded inverted filter is provided immediately at the downstream end of the impervious floor to relieve the uplift pressure.

113. (b)

The outer faces of the end sheet piles were much more effective than the inner ones and the horizontal length of the floor.

Undermining of the floor started from the tail end.

114. (c)

Regime silt charge is the minimum transported load consistent with fully active bed.

115. (a)

We know that for tile drains,

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

$$b = 8 + 0.3 = 8.3 \text{ m}$$

$$a = 8 \text{ m}$$

$$q = 4 \times 10^{-6} \text{ cumecs}$$

$$S = 30 \text{ m}$$

$$\therefore \quad k = \frac{Sq}{4\left(b^2 - a^2\right)} = \frac{30 \times 4 \times 10^{-6}}{4\left(8.3^2 - 8^2\right)}$$

$$= 6.13 \times 10^{-6} \text{ m/sec}$$

116. (b)

$$\text{Hydraulic mean radius, } R = \frac{5}{2}\frac{V^2}{f}$$

$$\Rightarrow \quad R = \frac{5}{2} \times \frac{1.4^2}{1.1} = 4.45 \text{ m}$$

117. (b)

A diversion headwork serves to divert the required supply into the canal from the river. It also controls the silt entry into the canal.

118. (c)

Bligh's designated the length of travel as the 'creep length', which is the sum of horizontal as well as vertical lengths of creep.

119. (a)

Given, $F = 70\%$

$$a = (F - 35) = 70 - 35 = 35 < 40\% \text{ (OK)}$$

$$b = (F - 15) = 70 - 15 = 55 \text{ but max value of } b = 40\%$$

$$\text{So,} \quad b = 40$$

$$c = (w_L - 40) = 35 - 40 = 0$$

$$d = (PI - 10) = 15 - 10 = 5\%$$

[Plasticity index = 35 – 20 = 15%]

$$GI = 0.2a + \frac{0.2}{20}bd + \frac{0.2}{40}ac$$

$$= 0.2 \times 35 + \frac{0.2}{20} \times 40 \times 5 + \frac{0.2}{40} \times 35 \times 0$$

$$= 9$$

120. (c)

Both the statements are in reference to the bituminous surface dressing.

121. (c)

$$\text{Given pavement width} = 10.5 \text{ m}$$

$$\text{So, number of lanes} = 3$$

$$\text{Extra widening, } W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$$\Rightarrow \quad W_e = \frac{3 \times 6 \times 6}{2 \times 400} + \frac{75}{9.5 \times \sqrt{400}}$$

$$= 0.135 + 0.4$$

$$= 0.535 \text{ m}$$

124. (c)

Both the given points are the reasons of why IRC recommends the use of spiral as transition curve.

125. (a)

$$V_{\text{avg}} = \frac{15 \times 50 + 10 \times 45 + 15 \times 60 + 5 \times 70}{15 + 10 + 15 + 5}$$

$$= 54.44 \text{ km/hr}$$

$$e = \frac{GV^2}{127R}$$

$$= \frac{1.676 \times 54.44^2}{127 \times \frac{1720}{2}} = 0.0455 \text{ m}$$

$$= 45.5 \text{ mm}$$

127. (c)

Both statements 1 and 2 are the requirements of a good tongue rail.

128. (d)

The given statements are the classification of the tunnels according to their alignment.

131. (c)

$$\text{Correction for elevation} = \frac{7}{100} \times \frac{1}{300} \times 600 \times 1600$$

$$= 224 \text{ m}$$

$$\text{Corrected length} = 1600 + 224 = 1824 \text{ m}$$

132. (a)

$$\text{Shrinkage factor} = \frac{9.8}{10} = 0.98$$

$$\text{R.F. of true scale} = \frac{0.98}{10 \times 100} = \frac{0.98}{1000}$$

R.F. of shrunk scale = R.F. of time scale × Shrinkage factor

$$= \frac{0.98 \times 0.98}{1000} = \frac{1}{1041.23}$$

133. (c)

For x = 2.86

Maximum error = 0.005 = δx

For y = 4.4

Maximum error = 0.05 = δy

So, Maximum error, $\delta s = y\delta x + x\delta y$

$= 4.4 \times 0.005 + 2.86 \times 0.05$

$= 0.165$

Alternatively,

Error in quantity can be found as:

	Maximum error $\delta x/\delta y$	**Probable error** $\delta x/\delta y$
x	±0.05	±0.025
y	±0.005	±0.0025

134. (b)

Great disadvantage of invar tape is that it is subjected to creep due to which it undergoes a small increase in length as time goes on.

136. (c)

Senstiveness can be increased by

- Increasing the internal radius of the tube.
- Increasing the diameter of the tube.
- Increasing the length of the bubble.
- Decreasing the viscosity of the liquid.

138. (c)

∵ Station F is 0.6 m higher than station A

∴ R.L. of F – R.L. of A = 0.6 m

Also, we have ΣB.S. – ΣF.S. = Last R.L. – First R.L.

⇒ ΣB.S. – ΣF.S. = 0.6 m

⇒ ΣB.S. = 0.6 + ΣF.S.

⇒ ΣB.S. = 0.6 + 3.0 = 3.6 m

But ΣB.S. = 2.3 + 2.3 – 1.6 + x = 3 + x

∴ $3 + x = 3.6$

⇒ $x = 0.6$ m

140. (a)

The datum scale is given by,

$$\delta_d = \frac{1}{10000} = \frac{f}{H} = \frac{(20/100)(m)}{H\ (m)}$$

$\Rightarrow$ H = 2000 m above M.S.L.

Relief displacement (d) is given by

$$d = \frac{rh}{H} = \frac{6.44 \times 250}{2000} = 0.805 \text{ cm}$$

141. (d)

Boiling occurs mostly in fine sands or silts. Seepage forces affect sands more than clays because clays have some inherent cohesion which holds the soil grains of clay together.

145. (d)

Muller-Breslau principle can also be used for determinate structures.

146. (d)

If the tunnel alignment contains curves or the changing grades, then the quantity of natural air expected to provided natural ventilation gets considerably reduced.

148. (d)

The accuracy of tacheometric method in case of measurement on even surface is lesser than that of chaining or taping, although the accuracy of the method on an uneven terrain exceeds that of the later.