DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 18

Full Syllabus Test 2 : Paper-II

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

DETAILED EXPLANATIONS

1. (a)

Deviation angle, $N = |n_2 - n_1| = |-5 - 3| = 8\%$

$= 0.08$

Assume, $L > \text{SSD}$

$$\therefore \quad L = \frac{NS^2}{4.4} = \frac{0.08 \times (100)^2}{4.4}$$

$= 181.82$ m

2. (c)

$$\text{Grade compensation} = \text{Minimum of} \begin{cases} \dfrac{30+\text{R}}{\text{R}} = \dfrac{30+150}{150} = 1.2\% \\ \dfrac{75}{R} = \dfrac{75}{150} = 0.5\% \end{cases}$$

$= 0.5\%$

Now, compensated gradient = Ruling gradient – Grade compensation

$= (5 - 0.5)\% = 4.5\%$

3. (b)

Superelevation is given as

$$e + f = \frac{V^2}{127\,R}$$

$$\Rightarrow \quad e + 0.15 = \frac{60^2}{127 \times 135}$$

$$\Rightarrow \quad e = 0.06$$

5. (d)

$$u = [60 - 0.5\text{k}]$$

$$\Rightarrow \quad u = 60\left[1 - \frac{k}{\left(\dfrac{60}{0.5}\right)}\right]$$

$$= 60\left[1 - \frac{k}{120}\right]$$

Now, on comparing with Greenshield's model,

$$u = U_{SF}\left[1 - \frac{k}{k_j}\right]$$

$$\Rightarrow \quad U_{SF} = 60 \text{ kmph}$$

and $k_j = 120$ veh/km

Now, maximum flow, $q_{max} = \left(\frac{U_{SF}}{2}\right)\left(\frac{k_j}{2}\right)$

$$= \left(\frac{60}{2}\right) \times \left(\frac{120}{2}\right) = 1800 \text{ veh/hr}$$

8. **(a)**

Stiffness matrix coefficient,

$$k_{11} = \frac{AE}{L} = \frac{400 \times 100 \times 10^3}{4000} = 10^4 \text{ N/mm}$$

9. **(b)**

Poisson's ratio, μ is given as

$$\mu = -\frac{\varepsilon_{lateral}}{\varepsilon_{longitudinal}}$$

$$\varepsilon_{lateral} = \frac{\Delta D}{D} = \frac{-0.004}{30}$$

$$\varepsilon_{longitudinal} = \frac{\Delta L}{L} = \frac{0.13}{300}$$

Now, $\mu = -\frac{(-0.004)}{30 \times \left(\frac{0.13}{300}\right)}$

$\Rightarrow$ $\mu = 0.3$

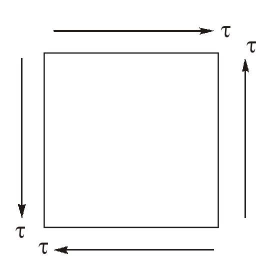
Now, $E = 2G(1 + \mu)$

$$200 = 2.G(1 + 0.3)$$

$\Rightarrow$ $G = \frac{100}{1.3} = 76.92 \text{ GPa}$

10. **(b)**

In pure shear, principal stress (tensile) and other principal stress (compressive) are developed on diagonal of element.



$\therefore$ $\sigma_{1/2} = \pm \tau$

11. (a)

As we know,

$$\frac{\gamma_{max}}{2} = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$= 10^{-6} \times \sqrt{\left(\frac{-120-(-40)}{2}\right)^2 + \left(\frac{160}{2}\right)^2}$$

$$= 10^{-6} \times \sqrt{40^2 + 80^2}$$

$$= 89.44 \times 10^{-6}$$

So, $\gamma_{max} = 2 \times 89.44 \times 10^{-6}$

$$= 178.88 \times 10^{-6}$$

12. (b)

According to principal strain theory,

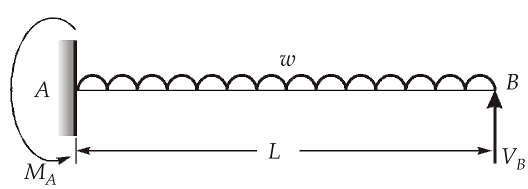
$$\frac{\sigma_1 - \mu\sigma_2}{E} \le \frac{\sigma_y}{E(FOS)}$$

$$\Rightarrow \quad \sigma_1 - \mu\sigma_2 = \frac{\sigma_y}{FOS}$$

$$\Rightarrow \quad 150 - 0.25(-100) = \frac{250}{FOS}$$

$$\Rightarrow \quad \text{FOS} = 1.43$$

13. (d)



Net vertical deflection at B, $(\delta)_B = 0$

$$\Rightarrow \quad \frac{V_B L^3}{3EI} - \frac{wL^4}{8EI} = 0$$

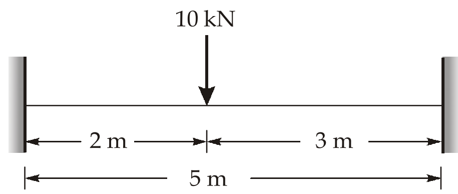
$$\Rightarrow \quad V_B = \frac{3wL}{8}$$

Now, $\Sigma M_A = 0$

$$\Rightarrow \quad -M_A + \frac{wL^2}{2} - \frac{3wL}{8} L = 0$$

$$\Rightarrow \quad M_A = \frac{wL^2}{8}$$

14. (b)



Vertical deflection under the point load is given as

$$\delta = \frac{Pa^3b^3}{3EI \cdot L^3}$$

$$= \frac{10\times10^3\times(2000)^3\times(3000)^3}{3\times2\times10^{13}\times(5000)^3}$$

$$= 0.288 \text{ mm}$$

15. (b)

Maximum shear stress in square section,

$$\tau_D = \frac{3}{2}\left(\tau_{avg}\right)$$

$$\Rightarrow \qquad \tau_D = \frac{3}{2}\frac{P}{(B\times B)} \qquad \text{...(1)}$$

and maximum shear stress in circular section,

$$\tau_0 = \frac{4}{3}\cdot\tau_{avg}$$

$$= \frac{4}{3}\cdot\frac{P}{\left(\frac{\pi}{4}\cdot D^2\right)}$$

$$= \frac{16}{3\pi}\cdot\frac{P}{D^2} \qquad \text{...(2)}$$

Now, $$\frac{\tau_0}{\tau_D} = \frac{\frac{16P}{3\pi D^2}}{\frac{3}{2}\cdot\frac{P}{B^2}} \qquad [B = D]$$

$$\Rightarrow \qquad \frac{\tau_0}{\tau_D} = \frac{32}{9\pi}$$

17. (d)

Rankine load is given as

$$\frac{1}{P} = \frac{1}{P_E}+\frac{1}{P_C}$$

$$\Rightarrow \quad \frac{1}{P} = \frac{1}{2000} + \frac{1}{3000}$$

$$\Rightarrow \quad P = 1200 \text{ kN}$$

18. (a)

$$\text{Power developed, } P = \frac{2\pi NT}{60}$$

$$\Rightarrow \quad 100 \times 10^3 = \frac{2\pi \times 100 \times T}{60}$$

$$\Rightarrow \quad T = 9549.296 \text{ N-m}$$

Now maximum shear stress, τ_{max} in the shaft is given as

$$\tau_{max} = \frac{16T}{\pi d^3}$$

$$= \frac{16 \times 9549.296 \times 10^3}{\pi \times (100)^3}$$

$$= 48.6 \text{ MPa}$$

23. (a)

Activity	(t_0) (days)	(t_m) (days)	(t_p) (days)	Standard deviation (σ) $\sigma = \left(\frac{t_p - t_0}{6}\right)$, (days)	Variance (σ^2) $(\text{days})^2$
A	8	14	20	2	4
B	7	21	31	4	16
C	5	15	23	3	9

Variance of activity A is the least and therefore activity A has the most reliable time estimates.

25. (a)

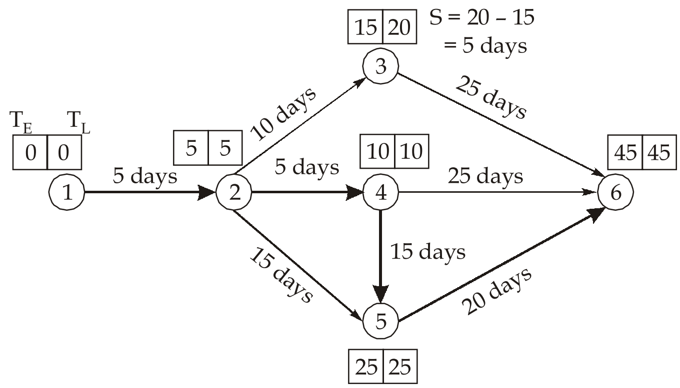
$$\text{Injury-severity rate} = \frac{\text{Number of days lost} \times 1000}{\text{Number of man-hours worked}}$$

$$= \frac{60 \times 1000}{250 \times 48 \times 50} = 0.10$$

26. (a)

Item rate contract is also known as unit price contract or schedule contract.

27. (a)



Hence, slack of event (3) is 5 days.

28. (b)

From sum of years digit method, depreciation is given as

$$\text{Depreciation at the end of } m^{th} \text{ year} = (C_i - C_s)\left[\frac{n-m+1}{\frac{n(n+1)}{2}}\right]$$

where, C_i is initial cost = Rs. 6000

C_s is salvage value = Rs. 1000

n is life of the equipment = 5

m = 2

Now,
$$D_2 = (6000-1000)\left[\frac{5-2+1}{\frac{5(5+1)}{2}}\right]$$
$$= \text{Rs. } 1333.33$$

29. (c)

Sinking fund factor (SFF) is given as

$$SFF = \left[\frac{i}{(1+i)^n - 1}\right]$$

where i is interest rate and n is useful life.

Now,
$$\text{SFF} = \left[\frac{0.08}{[1+0.08]^1 - 1}\right] = 1$$

33. (b)

Length of plastic hinge (L) is given as,

$$L_p = L\sqrt{1-\frac{1}{S.F.}}$$

Where, S.F. is shape factor,

$$S.F. = 1.5 \text{ for rectangular cross section.}$$

Now,

$$L_p = L\sqrt{1 - \frac{1}{1.5}}$$

$$= \frac{L}{\sqrt{3}}$$

34. (c)

Number of independent mechanisms, (k) is given as

$$k = N - D_s$$

where,

N is number of possible location of plastic hinges and D_s is degree of static indeterminacy.

Now, for a given frame,

$$D_s = 6 - 3 = 3$$

$$N = 6\ (A, C, F, D, E, B)$$

Hence,

$$k = 6 - 3 = 3$$

35. (a)

Design wind pressure, p_z is given as

$$p_z = 0.6(V_z)^2$$

where, V_z is design wind speed (m/s) i.e. 60 m/s

$$V_z = 60 \text{ m/s}$$

$$\therefore \quad p_z = 0.6 \times (60)^2$$

$$= 2160 \text{ N/m}^2$$

36. (a)

Nominal diameter of bolt, d = 20 mm

Length of the joint, l_j = 4 × 80 = 320 mm

[There are 5 bolts, so 4 nos. of pitches]

Since length of the joint (320 mm) is greater than 15d (15 × 20 = 300 mm), the shear capacity of the joint will be reduced by factor, β_{lj}.

$$\beta_{lj} = 1.075 - \frac{l_j}{200d}$$

$$= 1.075 - \frac{320}{200 \times 20}$$

$$= 0.995 \qquad [0.75 \le \beta_{lj} \le 1.0]$$

Now percentage reduction in shear capacity

$$= (1 - 0.995) \times 100 = 0.5\%$$

41. **(c)**

Thickness of base plate, (t) is given as

$$t = \sqrt{\frac{2.5w}{f_{bd}}(a^2 - 0.3b^2)}$$

$$\Rightarrow \quad t = \sqrt{\frac{2.5 \times 3}{225}((300)^2 - 0.3(300)^2)}$$

$$\Rightarrow \quad t = 45.83 \text{ mm}$$

$$\simeq 46 \text{ mm}$$

42. **(b)**

Effective thickness, t_{eff} for single V groove weld is given as

$$t_{eff} = \frac{5}{8}t_{min} = \frac{5}{8} \times 16 = 10 \text{ mm}$$

Safe tension capacity, P_T is given as

$$P_T = (l_{eff.}\ t_{eff.}) \times \sigma_{at}$$

$$= (150 \times 10) \times 150$$

$$= 225000 \text{ N} = 225 \text{ kN}$$

46. **(b)**

Minimum fineness of rapid hardening cement should be 325 m^2/kg.

48. **(a)**

1 m^3 of wet concrete gives 1.52 m^3 dry volume of concrete.

$$\text{Coarse aggregate proportion} = \frac{5.5}{1 + 2.5 + 5.5} = \frac{5.5}{9}$$

$$\text{So, volume of coarse aggregate} = \frac{5.5}{9} \times 1.52 = 0.93 \text{ m}^3$$

50. **(b)**

Kiln is a permanent structure whereas clamp is a temporary structure.

52. **(c)**

The thermoplastic variety softens on heating and hardens on cooling i.e. their hardness is a temporary property subjected to change with rise or fall of temperature and can be brought again to plastic stage on heating.

53. **(b)**

$$\text{Maturity of concrete} = \Sigma(\text{time} \times \text{temperature})$$

$$= 8 \times 12 \times [22° - (-11°)] + 8 \times 12 \times [11° - (-11°)]$$

$$= 5280°\text{C-hr}$$

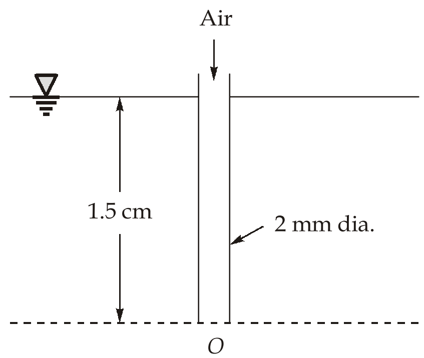
54. **(b)**

Bulk density for pine and oak are 0.6 and 0.57 respectively.

55. (c)

Class A is essential hydraulic lime and contains clay 15 to 25%.
Class B is semi hydraulic lime and contains clay 8 to 10%.
Class E is kankar lime and contains clay 15 to 25%.
Whereas class C is a fat clay and contains clay less than 8%.

56. (b)



$$\text{Pressure inside the bubble} = 200\ \text{N/m}^2$$

$$\text{Pressure outside the bubble} = \rho gh$$

$$= 0.85 \times 10^3 \times 9.81 \times \frac{1.5}{100}$$

$$= 125.07\ \text{N/m}^2$$

$$\Delta P = 200 - 125.07$$

$$= 74.93\ \text{N/m}^2$$

Now, $$\Delta P = \frac{2\sigma}{R}$$

$$\Rightarrow \quad 74.93 = \frac{2 \times \sigma}{1/1000}$$

$$\Rightarrow \quad \sigma = 0.037\ \text{N/m}$$

58. (a)

$$\phi = 2xy - x$$

$$u = \frac{-\partial \phi}{\partial x} = -[2y - 1]$$

$$v = \frac{-\partial \phi}{\partial y} = -2x$$

At point (2, 1),

$$u = -(2y - 1) = -[2 \times 1 - 1] = -1 \text{ unit}$$

$$v = -2x = -2 \times 2 = -4 \text{ unit}$$

$$\text{Velocity} = \sqrt{u^2 + v^2}$$

$$= \sqrt{(-1)^2 + (-4)^2}$$

$$= 4.12 \text{ units}$$

60. (d)

$$\text{Discharge, } Q = C_d \times A\sqrt{2gH}$$

where,
$$C_d = 0.98$$
$$A = 7.06 \times 10^{-4} \text{ m}^2$$
$$Q = 0.002 \text{ m}^3/\text{sec.}$$

$\therefore$ $$0.002 = 0.98 \times 7.06 \times 10^{-4} \times \sqrt{2 \times 9.81 \times H}$$

$\Rightarrow$ $$H = 0.43 \text{ m}$$

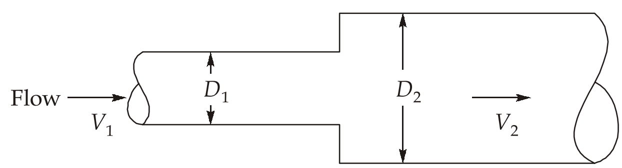
$\therefore$ $$\Delta H = \left(\frac{P_1}{\gamma} - \frac{P_2}{\gamma}\right) + (z_1 - z_2)$$

For horizontal nozzle, $z_1 = z_2$

$\therefore$ $$\Delta P = \gamma \cdot \Delta H$$
$$= 0.7 \times 9.81 \times 0.43 = 2.9 \text{ kPa}$$

61. (b)

For an expansion in a horizontal pipe,



Given: $$\frac{D_1}{D_2} = \frac{1}{\sqrt{2}}$$

$\therefore$ $$D_1 < D_2$$

$\Rightarrow$ $$V_1 < V_2$$

$\Rightarrow$ $$P_1 < P_2$$

$\therefore$ $$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \frac{(V_1 - V_2)^2}{2g}$$

$\Rightarrow$ $$\frac{P_2 - P_1}{\gamma} = \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - \frac{(V_1 - V_2)^2}{2g}$$

$$\frac{\Delta P}{\gamma} = \frac{V_2^2}{2g}\left[1 - \frac{V_2^2}{V_1^2}\right] - \frac{V_2^2}{2g}\left(1 - \frac{V_2}{V_1}\right)^2$$

$$= \frac{V_2^2}{2g}\left[1 - \left(\frac{D_1}{D_2}\right)^4\right] - \frac{V_1^2}{2g}\left(1 - \frac{D_1^2}{D_2^2}\right)^2$$

$$= \frac{V_1^2}{2g}\left[1 - \frac{1}{4}\right] - \frac{V_1^2}{2g}\left[1 - \frac{1}{2}\right]^2$$

$$= \frac{3}{4} \cdot \frac{V_1^2}{2g} - \frac{1}{4} \cdot \frac{V_1^2}{2g}$$

$$= \frac{1}{2}\left(\frac{V_1^2}{2g}\right)$$

$$\therefore \quad x = \frac{1}{2}$$

62. (a)

- In laminar flow, loss of head is proportional to the first power of viscosity.
- In laminar flow, velocity distribution is parabolic over the cross-section.

63. (d)

$$\frac{k_s}{\delta} = \frac{k_s}{\left[\frac{11.6\nu}{v_*}\right]}$$

and

$$v_* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\therefore \quad \frac{k_s}{\delta} = \frac{k_s v_*}{11.6 \times \nu} = \frac{0.12 \times 10^{-3} \times \sqrt{\frac{600}{1000}}}{11.6 \times 10^{-6}}$$

$$= 8.01 \simeq 8$$

65. (c)

At critical depth, $$\frac{Q^2}{g} = \frac{A_c^3}{T_c}$$

$$\Rightarrow \quad \frac{Q^2}{g} = \frac{y_c^6 \tan^3\theta}{2y_c \tan\theta} \qquad \left\{\begin{array}{l} \text{As } A_c = y_c^2 \tan\theta \\ \text{and, } T_c = 2y_c \tan\theta \end{array}\right\}$$

$$\Rightarrow \quad y_c = \left[\frac{2Q^2}{g \tan^2\theta}\right]^{1/5}$$

$$= \left[\frac{2 \times (3.84)^2}{9.81 \times (\tan 60)^2}\right]^{1/5} = 1 \text{ m}$$

66. (b)

$$\frac{dE}{dx} = S_0 - S_f$$

67. (d)

$$\text{Length of jump} = 6.9[y_2 - y_1]$$

$$= 6.6 \times [2 - 0.2]$$

$$= 12.42 \text{ m}$$

$$\simeq 12 \text{ m}$$

68. (c)

We know that, $$\frac{P_1}{D_1^5 N_1^3} = \frac{P_2}{D_2^5 N_2^3}$$

here,
$$D_1 = D_2$$
$$P_1 = 2000 \text{ W}$$
$$N_1 = 2500 \text{ rpm}$$
$$N_2 = 4000 \text{ rpm}$$

$\therefore$ $$P_2 = P_1\left(\frac{N_2}{N_1}\right)^3$$
$$= 2000 \times \left[\frac{4000}{2500}\right]^3$$
$$= 8192 \text{ W}$$

70. (a)

$$\text{Discharge, } Q = V_f \times \frac{\pi}{4}\left[D_h^2 - D_b^2\right]$$
$$= 16 \times \frac{\pi}{4}\left[2.25^2 - \left(\frac{2.25}{3}\right)^2\right]$$
$$= 56.55 \text{ m}^3/\text{sec.}$$

71. (b)

Duty at the head of channel = 0.85 times duty at the head of field

$\Rightarrow$ $$D = 0.85 \times \frac{8.64 \times B}{\Delta}$$

Here
$$B = 15 \text{ days}$$
$$\Delta = 60 - 15 = 45 \text{ cm}$$
$$D = \frac{\text{Area}}{\text{Discharge}}$$
$$\text{Area} = 0.7 \times 4000 = 2800 \text{ hac.}$$

$\therefore$ $$\frac{2800}{Q} = \frac{0.85 \times 8.64 \times 15}{0.45}$$

$\Rightarrow$ $$Q = 11.44 \text{ cumec}$$

72. (d)

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{++} + \text{Mg}^{++}}{2}}} = \frac{24}{\sqrt{\frac{4+2.2}{2}}} = 13.63$$

SAR is between 10 – 18. Therefore it is medium sodium water. Electrical conductivity is between 250 – 750 micro-mhos per cm at 25°C. The given water is classified of $S_2 - C_2$.

73. (a)

Lacey's design method is direct. Kennedy's method is trial and error.

74. (c)

As per Mitra's method,

$$B_x = \frac{B_0 B_f L_f}{L_f B_0 - (B_0 - B_f)x}$$

$$\Rightarrow \quad B_x = \frac{15 \times 9 \times 16}{16 \times 15 - [16 - 9]x}$$

$$\Rightarrow \quad B_x = \frac{2160}{240 - 7x}$$

∴ At $x = 8$ m,

$$B_x = \frac{2160}{240 - 7 \times 8} = 11.74 \text{ m}$$

75. (b)

$$\text{Regime scour depth, } R = 1.35\left[\frac{q^2}{f}\right]^{1/3}$$

$$\Rightarrow \quad R = 1.35\left[\frac{11.18^2}{1}\right]^{1/3}$$

$$\Rightarrow \quad R = 6.75 \text{ m}$$

$$\text{Regime velocity} = \frac{q}{R} = \frac{11.18}{6.75} = 1.66 \text{ m/sec}$$

$$\text{Velocity head} = \frac{V^2}{2g} = \frac{(1.66)^2}{2 \times 9.81} = 0.14 \text{ m}$$

76. (b)

Functions of distributary head regulator.

1. They regulate or control the supplies to the off taking channel.
2. They serve as a meter for measuring the discharge into the off-taking canal.
3. They control the silt entry in the off-taking canal.

77. (b)

For a particle on bed to be stationary

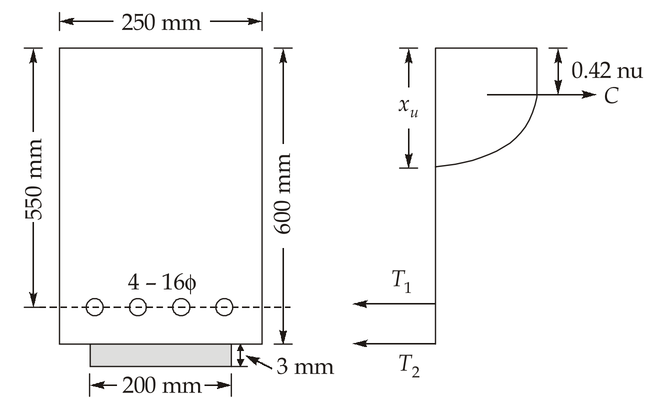
$$d \geq 11 \text{ RS}$$

Thus, $$d_{\text{min.}} = 11 \text{ RS}$$

where, $$R = \frac{By}{B + 2y} \simeq y \simeq 1 \text{ m}$$

$\therefore \quad d_{min} = 11\text{ RS}$
$= 11 \times 1 \times 0.0036 \text{ m} = 39.6 \text{ mm}$

80. (c)



Area of the plate, $A_p = 3 \times 200 = 600 \text{ mm}^2$

Area of steel bars, $A_{st} = 4 \times \frac{\pi}{4} \times 16^2 = 804.25 \text{ mm}^2$

Now, $C = T_1 + T_2$

$\Rightarrow \quad 0.36 \times f_{ck}\, x_u\, b = 0.87\, f_y\, A_{st} + 0.87 f_y\, A_p$

$\Rightarrow \quad 0.36 \times 20 \times x_u \times 250 = 0.87 \times 250 \times 804.25 + 0.87 \times 250 \times 600$

$\Rightarrow \quad x_u = 169.68 \text{ mm}$

$\therefore \quad \text{Lever arm} = (d - 0.42\, x_u)$
$= (550 - 0.42 \times 169.68)$
$= 478.73 \text{ mm}$

81. (b)

For $f_y = 250 \text{ MPa}, x_{u\,lim} = 0.53 \times d$

$\therefore \quad x_{u,lim} = 0.53 \times 550$
$= 291.5 \text{ mm}$

82. (c)

$M_u = T_1 \times (d - 0.42\, x_u) + T_2 \times [d_p - 0.42\, x_u]$

$\Rightarrow \quad M_u = 0.87 \times 250 \times 804.25 \times (550 - 0.42 \times 169.68) + 0.87 \times 250 \times 600$
$\times [601.5 - 0.42 \times 169.68]$
$= 152.9 \text{ kN-m} \simeq 153 \text{ kNm}$

83. (d)

Refer IS 456 : 2000 Clause 26.3.2.

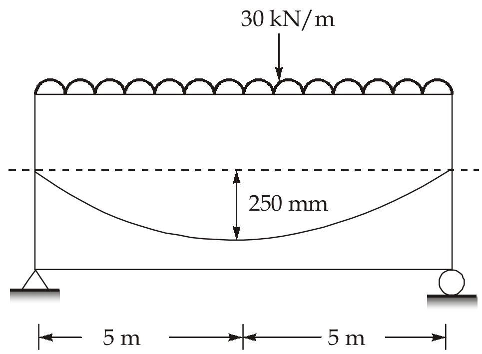
The horizontal distance between two parallel main reinforcement bars shall usually be not less than the greatest of the following:

- The diameter of the bar if the diameters are equal.
- The diameter of the largest bar if the diameters are unequal
- 5 mm more than the nominal maximum size of coarse aggregates.

NOTE: The vertical distance between two parallel main reinforcing bars should not be less than the greatest of the following:

- 15 mm.
- The diameter of the larger bar if the diameters are unequal.
- Two third of nominal maximum size of the coarse aggregate.

86. (d)



Intensity of equivalent load due to prestress,

$$w_p = \frac{8Ph}{l^2}$$

here, $w_p = 30$ kN/m

$h = 250$ mm $= 0.25$ m

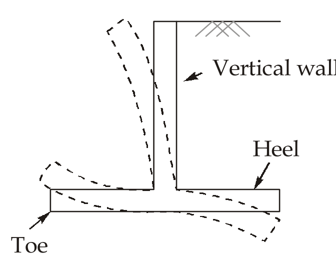
$l = 10$ m

$\therefore$ $$30 = \frac{8 \times P \times 0.25}{10^2}$$

$\Rightarrow$ $P = 1500$ kN

87. (b)

T-shaped retaining wall:



From the above diagram:

- The moment induced in the vertical wall causes tension on the face of the earth retained.
- The heel slab is subjected to net downward pressure that causes tension at the top of the slab.
- The toe slab is subjected to net upward pressure that causes tension at the bottom of the slab.

88. **(a)**

Time required for floc formation, conditioning and settling using iron salts is much less, hence detention time is reduced.

89. **(c)**

Here it is Type-III: zone settling where interparticle forces hold the particles together and mass of the particles subside as a whole.

91. **(b)**

Phosphates are measured colorimetrically.

93. **(b)**

For wastewater stream,

$$Q = 15000\,\text{m}^3/\text{d} \times \frac{1d}{24h} \times \frac{1h}{60\,\text{min}} \times \frac{1\,\text{min}}{60\,\text{sec}}$$

$$= \frac{15000}{24 \times 60 \times 60}\,\text{m}^3/\text{s}$$

$$= 0.17\ \text{m}^3/\text{s}$$

Dissolved oxygen of mix,

$$\text{DO}_{\text{mix}} = \frac{(DO)_w \cdot Q_w + (DO)_s \cdot Q_s}{Q_w + Q_s}$$

$$= \frac{2 \times 0.17 + 8 \times 0.5}{0.17 + 0.5}$$

$$= \frac{4.34}{0.67}$$

$$= 6.48 \simeq 6.5\ \text{mg}/l$$

95. **(b)**

The anaerobic digestion produces little residual biomass.

97. **(a)**

$$\text{Dilution ratio} = \frac{100}{\text{Percent of solution}} = \frac{100}{2} = 50$$

Now, BOD_5 = (Oxygen consumed) × Dilution ratio

= 15 × 50 = 750 mg/l

100. **(c)**

Since, both CO_2 and CH_4 are green house gases

Total greenhouse gases produced by 125 g of MSW

= 50g CO_2 + 25g CH_4 = 75 g

For 250 ton/day of MSW, greenhouse gas produced will be

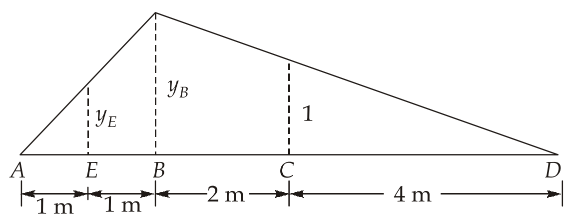
$$= 250 \times \frac{75}{125} \text{ ton/day}$$
$$= 150 \text{ ton/day}$$

101. (c)

$$\text{Damped frequency, } w_D = 30 \text{ rad/s}$$
$$\text{Damping ratio, } \xi = 0.51$$
$$\text{Now, natural frequency, } w_N = w_D\sqrt{1-\xi^2}$$
$$= 30 \times \sqrt{1-0.71^2}$$
$$= 30 \times \sqrt{1-0.5041} = 21.3 \text{ rad/s} \simeq 21 \text{ rad/s}$$

102. (c)

Using Muller Breaslau's principle, ILD for reaction at C is shown below.

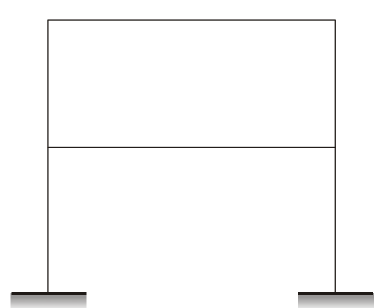


Now, $$y_B = 1 \times \frac{6}{4} = 1.5$$

So, $$y_E = y_B \times \frac{1}{2} = 1.5 \times \frac{1}{2} = 0.75$$

103. (a)

Degree of static indeterminacy, $D_s = 3m + r_e - 3j$
$= 3 \times 6 + 6 - 3 \times 6 = 6$



104. (d)

Equation of parabolic profile, $$y = \frac{4hx(l-x)}{l^2}$$

$$\text{Now, slope of cable, } \frac{dy}{dx} = \frac{4h}{l^2}(l-2x)$$

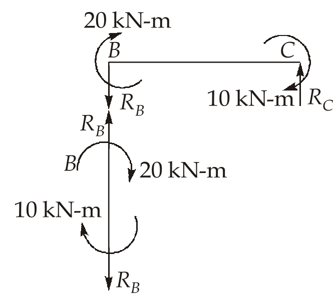
At $x = 10$ m,
$$\frac{dy}{dx} = \frac{4\times5\times(40-2\times10)}{40^2}$$
$$= \frac{4\times5\times20}{1600}$$
$$= 0.25 \text{ radian}$$

105. (b)

Distribution factor for BC and AC each is 0.5. FBDs of BC and AC are shown below.

In BC, $\Sigma M_C = 0 \Rightarrow -R_B \times 4 + 20 + 10 = 0$

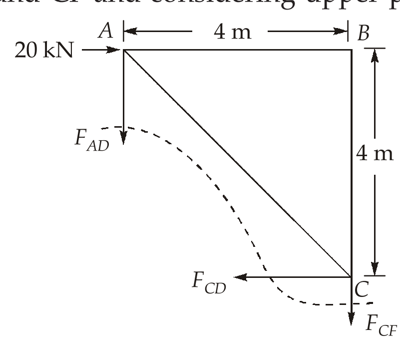
$$\Rightarrow \quad R = \frac{30}{4}\text{kN}$$



So, axial force in $AB = \dfrac{30}{4}\text{kN (Tension)}$

106. (d)

Cut a section through AD, CD and CF and considering upper portion of it.



$$\Sigma F_x = 0$$
$$\Rightarrow \quad F_{CD} - 20 = 0$$
$$\Rightarrow \quad F_{CD} = 20 \text{ kN (Tensile)}$$
$$\Sigma M_A = 0$$
$$\Rightarrow \quad F_{CF} \times 4 + F_{CD} \times 4 = 0$$
$$\Rightarrow \quad F_{CF} = -F_{CD} = -20 \text{ kN (Compressive)}$$
$$\Sigma F_y = 0$$
$$F_{AD} + F_{CF} = 0$$
$$\Rightarrow \quad F_{AD} = -F_{CF} = -(-20) \text{ kN (Tensile)}$$

107. (b)

$$\text{Horizontal thrust, } H = \frac{wl^2}{8h}$$

$$= \frac{10 \times 24^2}{8 \times 5} = 144 \text{ kN}$$

109. (c)

The beam can be transferred to

$$\text{So, moment developed at } A = \frac{60}{2} = 30 \text{ kN-m}$$

111. (a)

In perennial stream, even during the dry season, the water table will be above the bed of the stream.

112. (c)

For drought prone area = $0.2 \leq P \leq 0.4$

For chronically drought prone area = $P > 0.4$

113. (c)

For the entire 4 hr period, the direct runoff,

$$Q_{direct} = \frac{2.8 \times 10^4 \text{ m}^3}{2 \times 10^6 \text{ m}^2}$$

$$= 1.4 \times 10^{-2} \text{ m}$$

$$= 14 \text{ mm}$$

$$\text{Total rainfall, } P_{total} = 1(7) + 2(10) + 2(12)$$

$$= 51 \text{ mm}$$

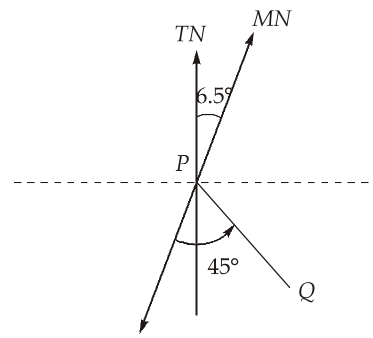
$$\therefore \quad \text{Infiltration loss} = 51 - 14$$

$$= 37 \text{ mm}$$

116. (b)

Metallic tapes are not easily broken.

117. (b)



$$\text{MN} = \text{Magnetic North}$$
$$\text{TN} = \text{True North}$$
$$\text{Magnetic bearing (in WCB)} = 180° - 45° = 135°$$
$$\text{True bearing} = \text{Magnetic bearing} \pm \text{Declination} = 135° + 6.5° = 141.5°$$

118. (c)

In transit method, the total error in latitudes and in departures is distributed in proportion to the latitudes and departures of the sides.

119. (a)

The scale expressed as R.F is given by,

$$\text{R.F} = \frac{f}{H - h_{avg}}$$

$$\Rightarrow \quad \frac{1}{8000} = \frac{20 \times 10^{-2}}{H - 1600}$$

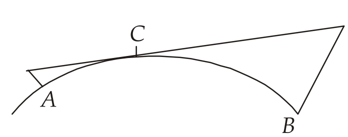
$$\Rightarrow \quad H - 1600 = 80 \times 20$$

$$\Rightarrow \quad H = 3200 \text{ m above MSL}$$

121. (a)

Nadir is the point on the lower portion of the celestial sphere marked by plumb line below the observer.

122. (a)



Let the observer is at A and the lighthouse is at B. The horizontal sight meets the horizon at C.

Distance between the observer and the lighthouse.

$$= AC + CB$$

$$= 3.85\sqrt{h_1} + 3.85\sqrt{h_2}$$

$$= 3.85\sqrt{8} + 3.85\sqrt{64}$$

$$= 3.85 \times 2.83 + 3.85 \times 8$$

$$= 10.89 + 30.8$$

$$= 41.69 \text{ m} \simeq 41.7 \text{ m}$$

123. (a)

$$\text{Third angle, } \angle C = 180° - (\angle A + \angle B)$$

$$= 180° - [42°30'\,20'' + 53°29'\,40'']$$

$$= 180° - [96°] = 84°$$

Weight of $(A + B)$ = Reciprocal of sum of reciprocals of weight of A and B

$$= \frac{1}{\frac{1}{2} + \frac{1}{3}} = \frac{6}{5}$$

$$\text{Weight of } C = \text{Weight of } [180° - (A + B)] = \frac{6}{5} = 1.2$$

125. (b)

$$\text{Dry density, } \rho_d = \frac{M_s}{V} = \frac{60}{40} = 1.5\,\text{gm/ml}$$

Now,
$$\rho_d = \frac{G\rho_w}{1+e}$$

$$\Rightarrow \quad 1.5 = \frac{2.71}{1+e}$$

$$\Rightarrow \quad e = \frac{2.71}{1.5} - 1$$

$$= 1.81 - 1 = 0.81$$

126. (a)

$$\text{Specific gravity of soil solids, } G = \frac{M_s}{M_s + M_4 - M_3}$$

where
M_s = Mass of soil solids
M_3 = Mass of (jar + soil + water)
M_4 = Mass of jar filled with water

$$\therefore \quad G = \frac{0.27}{0.27 + 1.5 - 1.67}$$

$$= \frac{0.27}{0.1} = 2.7$$

128. (b)

Edge to edge contacts between the clay particles form flocculated structure.

129. (d)

As per Skempton's theory,

$$\frac{D_f}{B} = \frac{4.5}{3} = 1.5 < 2.5$$

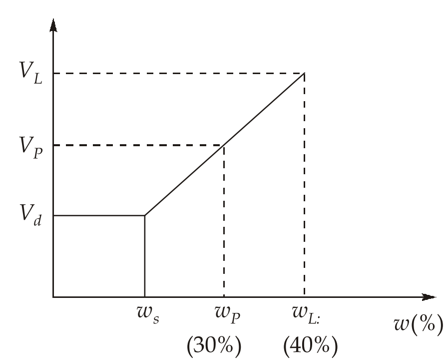
Net ultimate bearing capacity, $q_{nu} = C_u N_c = 5\left[1 + 0.2\frac{D_f}{B}\right]\left[1 + \frac{0.2B}{L}\right] \times C_u$

$$= 5\left[1 + \frac{0.2 \times 4.5}{3}\right]\left[1 + \frac{0.2 \times 3}{4}\right] \times 50$$

$\Rightarrow \quad = 373.75 \text{ kN/m}^2$

$\therefore$ Net safe bearing capacity, $q_{ns} = \frac{373.75}{2} \simeq 186.9 \text{ kN/m}^2$

130. (a)



Given, $w_p = 30\%, \quad w_L = 40\%$

$V_L - V_d = 0.35V_d$ and $V_p - V_d = 0.25V_d$

$\Rightarrow \quad V_L = 1.35V_d$ and $V_p = 1.25\,V_d$

From the graph,

$$\frac{V_L - V_p}{w_L - w_P} = \frac{V_P - V_d}{w_p - w_s}$$

$$\Rightarrow \quad \frac{1.35V_d - 1.25V_d}{40 - 30} = \frac{1.25V_d - V_d}{30 - w_s}$$

$$\Rightarrow \quad \frac{0.1}{10} = \frac{0.25}{30 - w_s}$$

$$\Rightarrow \quad w_s = 30 - \frac{0.25 \times 10}{0.1} = 5\%$$

131. (a)

Stability number, $S_n = \frac{c}{\gamma H_C}$

Friction circle method is based on total stress analysis.

132. (c)

Number of flow channels, $N_f = 5 - 1 = 4$

Number of equi-potential drops, $N_d = 22 - 1 = 21$

$\therefore$ Discharge per meter length, $Q = \dfrac{kHN_f}{N_d}$

$$\Rightarrow \quad 0.2 \times 10^{-3} = k \times 28 \times \frac{4}{21}$$

$$\Rightarrow \quad k = 3.75 \times 10^{-5} \text{ m/s}$$

133. (b)

Critical depth of unsupported cut, $H_C = \dfrac{4C}{\gamma\sqrt{k_a}}$

For $\phi_u = 0, k_a = 1$

$$\therefore \quad 8 = \frac{4C_u}{20\sqrt{1}}$$

$$\Rightarrow \quad C_u = 40 \text{ kN/m}^2$$

135. (a)

Effective overburden pressure at 14 m depth

$$= \gamma'(14)$$

$$= 10(14) = 140 \text{ kN/m}^2$$

Correction for overburden pressure:

$$N_1 = N_o\left[\frac{350}{\bar{\sigma} + 70}\right]$$

$$= 36 \times \left[\frac{350}{140 + 70}\right]$$

$$= 36 \times \frac{5}{3} = 60$$

Correction for dialatancy effect

$$N_2 = 15 + \frac{1}{2}(N_1 - 15)$$

$$= 15 + \frac{1}{2}(60 - 15)$$

$$= 15 + 22.5$$

$$= 37.5 \simeq 37$$

136. (c)

For falling head permeability test,

$$k = \frac{2.303aL}{A\ t}\log_{10}\left(\frac{h_1}{h_2}\right) \quad \text{...(1)}$$

Here, $t_1 = 10$ min, $h_1 = 30$ cm, $h_2 = 6$ cm

$t_2 = ?$, $h'_1 = 30$ cm, $h'_2 = 3$ cm

From equation (1),

$$\frac{1}{t_1}\log_{10}\left(\frac{h_1}{h_2}\right) = \frac{1}{t_2}\log_{10}\left(\frac{h'_1}{h'_2}\right)$$

$$\Rightarrow \frac{1}{10}\log_{10}\left(\frac{30}{6}\right) = \frac{1}{t_2}\log_{10}\left(\frac{30}{3}\right)$$

$$\Rightarrow \frac{1}{10}\log_{10}^{5} = \frac{1}{t_2}\log_{10}^{10}$$

$$\Rightarrow \frac{t_2}{10} = \frac{1}{\log_{10}^{5}} = 1.43 \qquad \left(\because \log_{10}^{5} = 0.669\right)$$

$$\Rightarrow t_2 = 14.3 \text{ minutes}$$

137. (a)

From Horonjeff's equation,

$$R = \frac{0.388W^2}{\frac{T}{2} - S}$$

Here, $W = 18$ m

$T = 22.5$ m

$S = 9.5$ m

$$\therefore R = \frac{0.388 \times 18^2}{\frac{22.5}{2} - 9.5} = \frac{125.7}{1.75} \simeq 71.8 \text{ m}$$

138. (d)

Intermediate straight portion distance,

$$S = (D - G)N - G\sqrt{1 + N^2}$$

Total/Overall length of crossover $= 4GN + S$

$$= 4GN + (D - G)N - G\sqrt{1 + N^2}$$

$$= DN + G\left(3N - \sqrt{1 + N^2}\right)$$

145. (c)

Blended cements are most preferred when both sulphates and chlorides are present in the environment at the same time.

146. (a)

Timbr sections change in volume with change in season due to change of environmental factors like temperature, humidity etc., therefore while ftting wooden window shuters should be fitted leaving proper tolerance for dimensional change.

148. (a)

Soil nutrients are preserved because of reduction in deep percolation losses. Moreover, feeding of water enriched with fertilizers results in proper maintenance and preservation of nutrients at optimum level.

149. (a)

The disturbance caused to the soil sample used in laboratory changes the structure of soil.

150. (d)

In anaerobic digestion, organic acids are converted into CO_2 and CH_4.

■■■■