DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 4

Section A : Solid Mechanics [All Topics]
Section B : Geo-technical & Foundation Engineering-1 [Part Syllabus]
Section C : Environmental Engineering-1 [Part Syllabus]

1.	(c)	16.	(a)	31.	(a)	46.	(d)	61.	(c)
2.	(c)*	17.	(a)	32.	(b)	47.	(c)	62.	(d)
3.	(a)	18.	(c)	33.	(d)	48.	(c)	63.	(a)
4.	(b)	19.	(d)	34.	(b)	49.	(b)	64.	(b)
5.	(b)	20.	(b)	35.	(c)	50.	(b)	65.	(b)
6.	(d)	21.	(c)	36.	(b)	51.	(b)	66.	(d)
7.	(b)	22.	(d)	37.	(a)	52.	(d)	67.	(c)
8.	(c)	23.	(a)	38.	(c)	53.	(d)	68.	(b)
9.	(a)	24.	(b)	39.	(d)	54.	(c)	69.	(c)
10.	(b)	25.	(d)	40.	(d)	55.	(c)	70.	(b)
11.	(c)	26.	(a)	41.	(d)	56.	(c)	71.	(c)
12.	(a)	27.	(a)	42.	(c)	57.	(a)	72.	(b)
13.	(b)	28.	(c)	43.	(b)	58.	(c)	73.	(d)
14.	(b)	29.	(a)	44.	(d)	59.	(b)	74.	(d)
15.	(c)*	30.	(c)	45.	(b)	60.	(d)	75.	(a)

*Q. 2. *Answer Key & Explanation has been updated*

*Q. 15. *Answer Key & Explanation has been updated*

DETAILED EXPLANATIONS

1. (c)

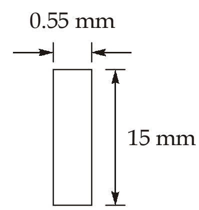
There is sudden jump in bending moment diagram at point C of 2000 Nm.

$\therefore$ A couple of 2000 Nm acts at point C.

2. (c)

Strain-softening region in stress strain curve is also known as post ultimate stress.

3. (a)



$$\because \quad \frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$\Rightarrow \quad \frac{\sigma}{y} = \frac{E}{R}$$

$$\Rightarrow \quad \sigma = \frac{Ey}{R}$$

Given, $E = 210$ GPa

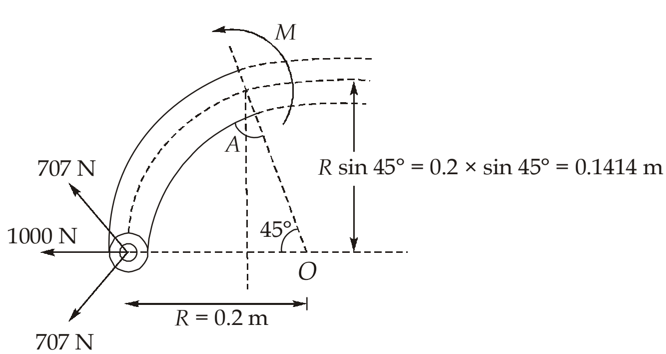
$$y = \frac{0.55}{2} = 0.275 \text{ mm}$$

$$R = \frac{420}{2} = 210 \text{ mm}$$

$$\therefore \quad \sigma = \frac{210 \times 10^3 \times 0.275}{210}$$

$$\therefore \quad \sigma = 275 \text{ MPa}$$

4. (b)



$$M = 1000 \times 0.1414$$
$$= 141.4 \text{ Nm}$$

5. (b)

$$M = EI\frac{d^2y}{dx^2} = EIy''$$

$$V = \frac{dM}{dx} = \frac{d}{dx}\left(\frac{EId^2y}{dx^2}\right) = (EIy'')'$$

$$\text{Load intensity, } w = \frac{dV}{dx} = \frac{d^2}{dx^2}\left(EI\frac{d^2y}{dx^2}\right) = (EIy'')''$$

6. (d)

$\because$ $\sigma_1 + \sigma_2 = \sigma_x + \sigma_y$

$\Rightarrow$ $200 + \sigma_2 = 50 + 100$

$\Rightarrow$ $\sigma_2 = -50$ MPa (compressive)

Also, we know that

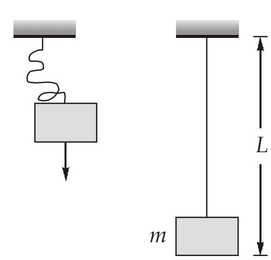
$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$\Rightarrow$ $$200 = \frac{50+100}{2} + \sqrt{\left(\frac{50-100}{2}\right)^2 + \tau_{xy}^2}$$

$\Rightarrow$ $$(125)^2 = (25)^2 + \tau_{xy}^2$$

$\Rightarrow$ $$\tau_{xy} = 50\sqrt{6} \text{ MPa}$$

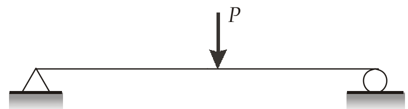
7. (b)



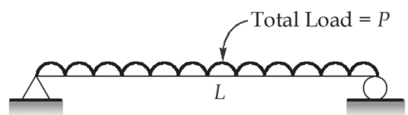
$$\frac{1}{2}mv^2 = \frac{\sigma^2}{2E} \times AL$$

$\Rightarrow$ $$\sigma = \sqrt{\frac{mv^2E}{AL}} = v\sqrt{\frac{mE}{AL}}$$

8. (c)



$$\Delta_{\max 1} = \frac{PL^3}{48EI}$$



$$\Delta_{\max 2} = \frac{5PL^3}{384EI}$$

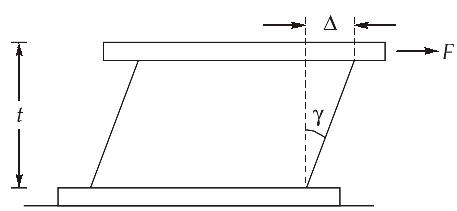
% decrease in maximum deflection

$$= \frac{\Delta_{\max 1} - \Delta_{\max 2}}{\Delta_{\max 1}} \times 100\%$$

$$= \frac{\frac{1}{48} - \frac{5}{384}}{\frac{1}{48}} \times 100\% = 37.5\%$$

9. (a)

$$a = 50 \text{ mm}, b = 25 \text{ mm}$$



$$\gamma = \frac{\Delta}{t}$$

$$\tau = G\gamma = \frac{G\Delta}{t}$$

$$\text{Force} = \tau \times \text{Area} = \tau \times a \times b$$

$$= \frac{G\Delta}{t} \times a \times b$$

$\therefore$

$$K_s = \frac{F}{\Delta} = \frac{G\Delta \times a \times b}{t \times \Delta} = \frac{Gab}{t}$$

$$K_s = \frac{0.68 \times 50 \times 25}{8} = 106.25 \text{ N/mm}$$

10. (b)

$\because$ $\sigma_x = \sigma_y = \sigma_z = -p$ (say)

We know that,

$$\varepsilon_v = \frac{(\sigma_x + \sigma_y + \sigma_z)(1-2\mu)}{E}$$

$$\varepsilon_v = \frac{-3p(1-2\mu)}{E}$$

$$\frac{-p}{\varepsilon_v} = \frac{E}{3(1-2\mu)}$$

11. (c)

$$\text{Section modulus, } Z = \frac{\pi d^3}{32}$$

$$\text{Polar modulus, } Z_P = \frac{\pi d^3}{16}$$

$$\therefore \quad \frac{Z}{Z_P} = \frac{1}{2}$$

$$\because \quad M = fZ, T = qZ_P$$

$$\therefore \quad \frac{M}{T} = \frac{fZ}{qZ_P} = \frac{f}{2q}$$

Strain energy stored per unit volume due to $M = \frac{f^2}{2E}$

Strain energy stored per unit volume due to $T = \frac{q^2}{2G} = \frac{q^2}{E}(1+\mu)$

$$\because \quad E = 2G(1+\mu)$$

$$\therefore \quad \frac{q^2}{E}\times(1+0.3) = \frac{f^2}{2E}$$

$$\Rightarrow \quad \frac{f}{q} = \sqrt{2.6} = 1.61$$

$$\therefore \quad \frac{M}{T} = \frac{f}{2q} = \frac{1.61}{2} = 0.805$$

12. (a)

$$K_{12} = \frac{\phi_{xy}}{2}$$

$$\tau = G \times \phi_{xy}$$

$$\tau = 25 \text{ MPa}$$

$$\therefore \quad G = \frac{E}{2(1+\mu)} = \frac{2\times10^5}{2(1+0.25)}$$

$$= 8 \times 10^4 \text{ MPa}$$

$$\because \quad \tau = G \times \phi_{xy}$$

$$\Rightarrow \quad 25 = 8 \times 10^{-4} \times \phi_{xy}$$

$$\Rightarrow \quad \phi_{xy} = 3.125 \times 10^{4}$$

So,

$$K_{12} = \frac{\phi_{xy}}{2} = \frac{3.125 \times 10^{-4}}{2}$$

$$= 1.5625 \times 10^{-4}$$

13. (b)

Let lengths of segments *AB*, *BC* and *CD* to be L_1, L_2 and L_3 respectively.

Angle of twist $\theta = \frac{TL}{GJ}$ is same for all the three segments. So,

$$\frac{L_1}{J_1} = \frac{L_2}{J_2} = \frac{L_3}{J_3} = \frac{L_1 + L_2 + L_3}{J_1 + J_2 + J_3} = \frac{L}{J_1 + J_2 + J_3}$$

$$J_1 + J_2 + J_3 = \frac{\pi}{32}[(100^4 - 60^4) + 100^4 + 85^4]$$

$$= \frac{\pi}{32}(2.393 \times 10^8)$$

So,

$$AB = L_1 = \frac{J_1 L}{J_1 + J_2 + J_3}$$

$$= \frac{(100^4 - 60^4) \times 3}{2.393 \times 10^8} = 1.1 \text{ m}$$

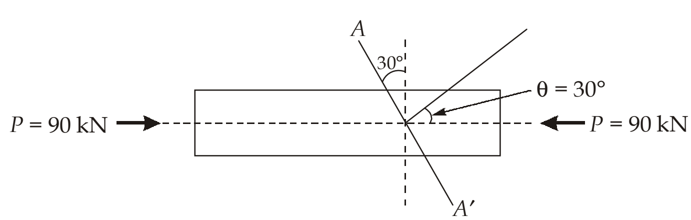
$$BC = L_2 = \frac{J_2 L}{J_1 + J_2 + J_3} = \frac{100^4 \times 3}{2.393 \times 10^8} = 1.25 \text{ m}$$

$$CD = L_3 = L - L_1 - L_2 = 3 - 1.1 - 1.25 = 0.65 \text{ m}$$

14. (b)

Compliance of a spring is the reciprocal of the spring constant or the deflection produced by a load of unit value.

15. (c)



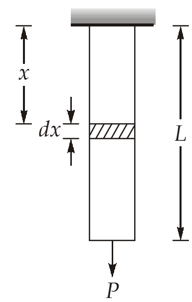
$$\sigma_x = \frac{P}{A} = \frac{90 \times 10^3}{1200} = 75 \text{ N/mm}^2$$

$$\sigma_\theta = \sigma_x \cos^2\theta = 75 \cos^2 30° = 56.25 \text{ N/mm}^2$$

$$\tau_\theta = \sigma_x \sin\theta \cos\theta = 75 \cos 30° \sin 30°$$

$$= 32.476 \text{ N/mm}^2 \simeq 32.48 \text{ N/mm}^2$$

16. (a)



The axial load P_x acting on the element shown shaded in the figure is

$$P_x = \gamma A(L - x) + P$$

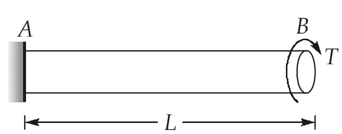
$$U = \int_0^L \frac{P_x^2 dx}{2EA}$$

$$\Rightarrow \quad U = \int_0^L \frac{[\gamma A(L-x)+P]^2 dx}{2EA}$$

$$\Rightarrow \quad U = \frac{\gamma^2 AL^3}{6E} + \frac{\gamma PL^2}{2E} + \frac{P^2 L}{2EA}$$

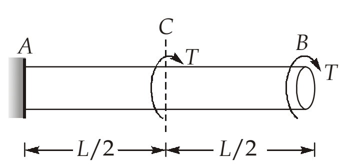
17. (a)

Case I:



$$U_1 = \frac{T^2 L}{2GJ}$$

Case II :



$$U_2 = \underbrace{\frac{T^2\left(\frac{L}{2}\right)}{2GJ}}_{BC} + \underbrace{\frac{(2T)^2 \times \left(\frac{L}{2}\right)}{2GJ}}_{CA}$$

$$\Rightarrow \quad U_2 = \frac{5}{4}\frac{T^2 L}{GJ} = \frac{5}{2}\left(\frac{T^2 L}{2GJ}\right) = \frac{5}{2}U_1$$

$$\therefore \quad \text{Ratio of two strain energy} = \frac{U_1}{U_2} = \frac{1 \times 4}{2 \times 5} = \frac{2}{5} = 0.4$$

18. (c)

$\because \quad E = 2G(1 + \mu)$

$\Rightarrow \quad E = 2 \times 8 \times 10^4(1 + 0.25)$

$\Rightarrow \quad E = 2 \times 10^5 \text{ N/mm}^2$

$$\therefore \quad \sigma_x = \frac{E}{(1+\mu)(1-2\mu)} \times [(1-\mu)\in_x + \mu(\in_y + \in_z)]$$

$$\Rightarrow \quad \sigma_x = \frac{2\times10^5}{(1+0.25)(1-0.25\times2)} \times [(1-0.25)\times340\times10^{-6}$$

$$+ 0.25 \times (110\times10^{-6} + (-200\times10^{-6}))]$$

$\Rightarrow \quad \sigma_x = 74.4 \text{ N/mm}^2$

19. (d)

$$P_E = \frac{\pi^2 EI}{L_e^2}$$

$$\therefore \quad \frac{P_2}{P_1} = \frac{I_2}{I_1} = \frac{\frac{\pi}{64}d_2^4}{\frac{\pi}{64}d_1^4}$$

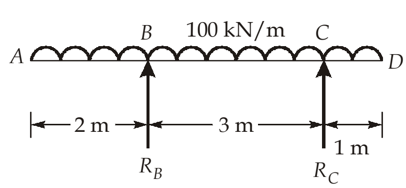
$$\Rightarrow \quad \frac{P_2}{P_1} = \left(\frac{d_2}{d_1}\right)_4^4$$

$$\Rightarrow \quad \frac{P_2}{P_1} = \left(\frac{0.7D_1}{D_1}\right)^4 = 0.24$$

$\Rightarrow \quad P_2 = 0.24\, P_1$

$\therefore$ Percentage reduction = 76%

20. (b)



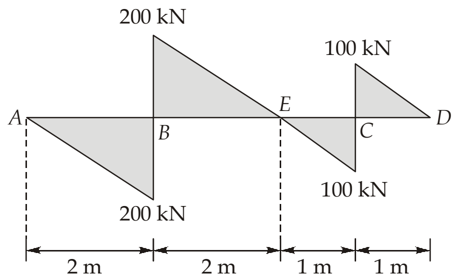
$\Sigma M_B = 0$

$100 \times 2 \times 1 + R_C \times 3 = 100 \times 4 \times 2$

$R_C = 200 \text{ kN}$

$R_C + R_B = 600 \text{ kN}$

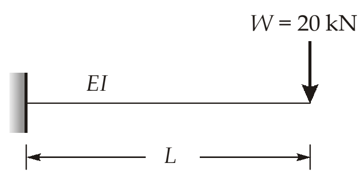
$\Rightarrow \quad R_B = 400 \text{ kN}$



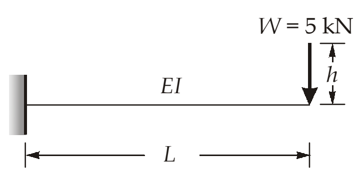
SFD

$$(S.F)_{max} = 200 \text{ kN}$$
$$M_B = 100 \times 2 \times 1 = 200 \text{ kNm}$$
$$M_E = R_B \times 2 - 100 \times 4 \times 2 = 0$$
$$M_C = 100 \times 0.5 = 50 \text{ kNm}$$
$$(M)_{max} = 200 \text{ kNm}$$

21. (c)

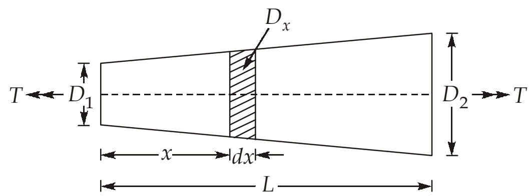


$$(\sigma_{static})_{max} = 20 \text{ MPa}$$
$$\delta_{static} = 10 \text{ mm}$$



$$\sigma_{static} = 5 \text{ MPa} \qquad \text{(load becomes 1/4th)}$$
$$\delta_{static} = 2.5 \text{ mm}$$
$$\sigma_{impact} = \sigma_{st} \times \text{impact factor}$$
$$40 = 5\left[1+\sqrt{1+\frac{2h}{\delta_{static}}}\right]$$
$$= 5\left[1+\sqrt{1+\frac{2h}{2.5}}\right]$$
$$h = 60 \text{ mm}$$

22. (d)



Consider an element of length dx at distance x from the smaller diameter end.

The diameter of the elemental slice is

$$D_x = D_1 + \left(\frac{D_2 - D_1}{L}\right)x = D_1 + kx$$

where, $$k = \frac{D_2 - D_1}{L}$$

Corresponding polar moment of inertia of the shaft at the section under consideration

$$J_x = \frac{\pi D_x^4}{32} = \frac{\pi(D_1 + kx)^4}{32}$$

The angle of twist over the length dx can be obtained from the relation

$$\frac{T}{J_x} = \frac{Gd\theta_x}{dx}$$

$$d\theta_x = \frac{Tdx}{GJ_x}$$

Therefore, $$d\theta_x = \frac{T}{G}\left[\frac{32}{\pi(D_1 + kx)^4}\right]dx$$

The total angle of twist over the entire length is

$$\theta = \frac{32T}{\pi G}\int_0^L \frac{dx}{(D_1 + kx)^4} = \frac{32T}{\pi G}\int_0^L (D_1 + kx)^{-4}\,dx$$

$$= \frac{32T}{\pi G}\left[-\frac{(D_1 + kx)^{-3}}{3k}\right]_0^L = \frac{32T}{3\pi Gk}\left[-\frac{1}{(D_1 + kx)^3}\right]_0^L$$

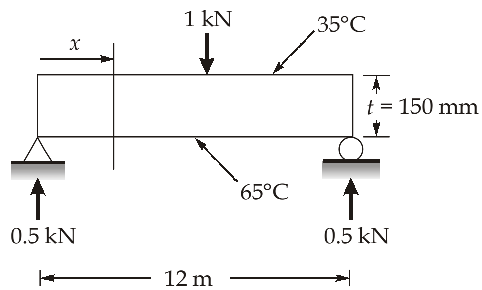
$$= \frac{32T}{3\pi Gk}\left[-\frac{1}{(D_1 + kL)^3} + \frac{1}{D_1^3}\right]$$

$$= \frac{32TL}{3\pi G(D_2 - D_1)} \times \left(\frac{D_2^3 - D_1^3}{D_1^3 D_2^3}\right)$$

$$= \frac{32TL}{3\pi G} \times \left(\frac{D_2^2 + D_1^2 + D_1 D_2}{D_1^3 D_2^3}\right)$$ (Standard result, remember)

23. (a)

Apply unit load at mid span



Moment due to unit load, $m = \frac{1}{2}x$ for $0 \le x \le 6$

As bottom temperature is more, hence

$$d\theta = \frac{dx\,\alpha T}{t} = \frac{dx \times 0.75 \times 10^{-7} \times (65-35)}{0.150}$$

$$d\theta = 1.5 \times 10^{-5}\,dx$$

Using unit load method,

$$1 \cdot \Delta = m \cdot d\theta$$

$$1 \cdot \Delta = 2\int_0^6 \frac{x}{2} \times 1.5 \times 10^{-5}\,dx$$

$$\Delta = 2.7 \times 10^{-4}\text{ m}$$

$$= 0.27\text{ mm}$$

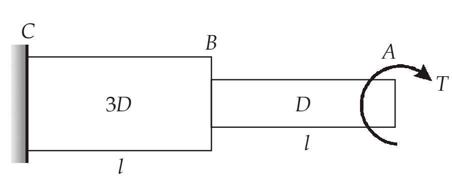
24. (b)

$$\text{Resilience} = \frac{1}{2} \times 70 \times 0.005 \times 10^6 = 17.5 \times 10^4\text{ Nm/m}^3$$

$$\text{Toughness} = 17.5 \times 10^4 + \left\{\left[\frac{(70+110)}{2}\right]\right\} \times 0.01 \times 10^6$$

$$= 107.5 \times 10^4\text{ Nm/m}^3$$

25. (d)



$$\text{Angle of twist, } \theta = \frac{Tl}{GJ}$$

$$\Rightarrow \quad \theta \propto \frac{1}{J} \propto \frac{1}{(\text{Diameter})^4}$$

$$\Rightarrow \qquad \theta_B = \frac{Tl}{GJ_{BC}} = \frac{Tl \times 32}{G\pi \times (3D)^4}$$

Also,
$$\theta_A = \theta_B + \frac{Tl}{GJ_{AB}}$$
$$= \frac{Tl \times 32}{G\pi \times (3D)^4} + \frac{Tl \times 32}{G\pi \times (D)^4}$$
$$= \frac{Tl \times 32}{G\pi}\left(\frac{1}{(3D)^4} + \frac{1}{(D)^4}\right)$$

$$\therefore \qquad \frac{\theta_A}{\theta_B} = \frac{\frac{1}{(3D)^4} + \frac{1}{D^4}}{\frac{1}{(3D)^4}} = \frac{1+81}{1} = 82$$

26. (a)

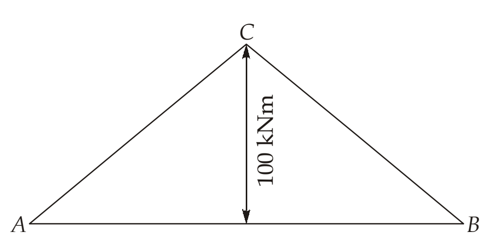
1. $\tau_{max,cir} = \frac{4}{3}\left(\frac{F}{A}\right) < \tau_{max,rect} = \frac{3}{2}\left(\frac{F}{A}\right)$
2. Circular section has same moment of inertia in all directions and is preferred as compression member.
3. In torsion, circular section has same stress at all the points which are equidistant from the center.
4. For bending, $I_{Cir} < I_{Rect.}$ for same area of cross-section.

27. (a)

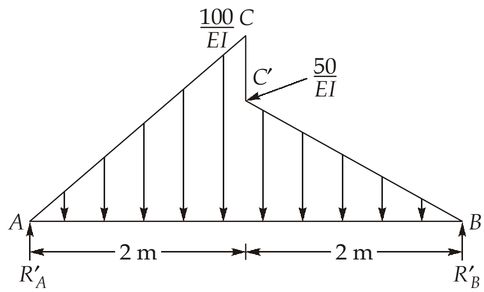
$$A = 50 \times 150 = 7500 \text{ mm}^2$$
$$\bar{y} = 25 \text{ mm from } NA$$
$$P = \frac{\sigma_{max}}{y_{max}} A\bar{y}$$
$$= \frac{8}{100} \times 7500 \times 25$$
$$= 15000 \text{ N}$$
$$= 15 \text{ kN}$$

28. (c)

BM diagram of given beam



Conjugate beam

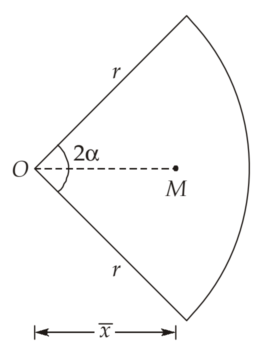


Taking moments about *B*

$$R'_A \times 4 = \frac{1}{2}\times 2\times\frac{100}{EI}\left(2+\frac{2}{3}\right) + \frac{1}{2}\times 2\times\frac{50}{EI}\times 2\times\frac{2}{3}$$

$\Rightarrow$ $$R'_A = \frac{250}{3EI}$$

29. (a)



$$\bar{x} = \frac{2r\sin\alpha}{3\alpha}$$

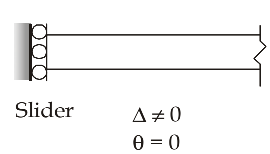
$$\alpha = 60° = \frac{\pi}{3}\text{ radians}$$

$\therefore$ $$\bar{x} = \frac{2\times r\times\sin 60°}{3\times\frac{\pi}{3}}$$

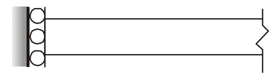
$$\bar{x} = \frac{\sqrt{3}}{\pi}r$$

30. (c)

Real Beam :



Conjugate Beam :



31. (a)

Tresca's Theory or maximum shear stress theory is the most conservative.

32. (b)

$$\sigma_1 = 100 \text{ N/mm}^2$$
$$\sigma_2 = \sigma_3 = 0$$

Maximum shear strain energy

$$U = \frac{\mu+1}{6E}[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]$$

$\therefore$ $$E = 2G(1+\mu)$$

$\therefore$ $$U = \frac{1}{12G}[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]$$

$\Rightarrow$ $$U = \frac{1}{12G}(100^2+100^2)$$

$$U = \frac{5000}{3G}$$

33. (d)

Shear span is zone of constant shear force.

35. (c)

During strain hardening, specimen undergoes change in crystalline structure resulting in increased resistance of the material to further deformation.

37. (a)

Shear centre is also sometimes called as centre of twist.

38. (c)

Beam of uniform strength can be made by varying both depth and width.

40. (d)

CL soil is used in core of an embankment.

41. (d)

Given data:

$$w_P = 25\%$$
$$w_L = 35\%$$
$$V_L - V_d = 0.35\ V_d$$
$$V_P - V_d = 0.22\ V_d$$
$$V_L = 1.35\ V_d$$

$$V_P = 1.22\ V_d$$

$$R = \frac{\left(\frac{V_1 - V_2}{V_d}\right)}{w_1 - w_2} \times 100 = \frac{\frac{V_L - V_P}{V_d}}{w_L - w_P} \times 100$$

$$= \frac{\left(\frac{1.35V_d - 1.22V_d}{V_d}\right)}{35 - 25} \times 100$$

$$R = \frac{0.13}{10} \times 100 = 1.3$$

42. (c)

Assuming area of base course = 1 m^2

∴ $V = 0.5 \times 1 = 0.5\ m^3$

∴ Volume of voids, $V_v = nV = 0.5 \times 0.5 = 0.25\ m^3$

∴ $V_w = 0.7V_v = 0.7 \times 0.25 = 0.175\ m^3$

∴ $V_a = V_v - V_w = 0.25 - 0.175 = 0.075\ m^3$

Required amount of water to fully saturate the base course

$= 0.075\ m^3$

∴ Amount of rainfall $= \frac{0.075\ m^3}{1\ m^2} = 0.075\ m = 75\ mm$

43. (b)

Clay soils are normally associated with water and their properties are greatly influenced by the presence of water. This is in marked contrast to the granular soils which generally are not sensitive to the amount of water present.

44. (d)

∵ $$\gamma_t = \frac{G \cdot \gamma_w (1 + w)}{1 + e}$$

$G = 2.7,\ \gamma_w = 9.81\ kN/m^3$

$e = 0.6$

∵ $Se = Gw$

⇒ $$w = \frac{0.8 \times 0.6}{2.7} = 0.18$$

∴ $$\gamma_t = \frac{2.7 \times 9.81 \times (1 + 0.18)}{1 + 0.6}$$

⇒ $\gamma_t = 19.53\ kN/m^3$

45. (b)

Secondary consolidation becomes important for certain types of soil, such as peats and soft organic clays. For stiff clays or preconsolidated clays, this component is relatively minor, as primary consolidation accounts for a major share of the total settlement.

Granular materials exhibit a compressibility behaviour quite distinct from that of clay. The granular soil compresses almost immediately upon loading but the compression is relatively small, whereas a fine-grained soil exhibits time-dependent consolidation and the compression is rather large.

46. (d)

- Measurement of permeability of the soil can be made only in the fixed ring test.
- $K \propto \frac{1}{S_s^2}$ where, S_s is specific surface area

47. (c)

$\because$ $\Delta U = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$

$\because$ $B = 1$, since the soil is completely saturated.

Also, $\Delta\sigma_3 = 0$

In conventional triaxial test, the cell pressure is maintained constant all through.

$$\therefore \quad A_f = \frac{\Delta U_f}{\Delta\sigma_{1f}} = \frac{75}{150} = 0.5$$

48. (c)

Given: $w_L = 60\%, I_P = 30\%$

$$\text{Equation of } A \text{ line } (I_p) = 0.73(w_L - 20)$$
$$= 0.73 \times (60 - 20)$$
$$= 29.2\%$$

Since $(I_P)_{soil} > (I_P)_{A\text{-line}}$, hence soil is clay

Also, $w_L > 50\%$

Therefore, soil is classified as CH.

49. (b)

$$i_{cr} = \frac{G-1}{1+e} = (G - 1)(1 - n)$$
$$= (2.6 - 1)(1 - 0.5)$$
$$= 0.8$$

$$\because \quad \text{FOS} = \frac{i_{cr}}{i_e}$$

$$\Rightarrow \quad i_e = \frac{0.8}{2.5} = 0.32$$

50. (b)

In the assumptions of Rankine's earth pressure theory, the backfill is considered cohesionless. The theory has been extended by Bell (1915) to cover the case of backfills possessing both cohesion and friction.

51. (b)

$$K_H = \frac{K_1H_1 + K_2H_2 + K_3H_3}{H_1 + H_2 + H_3}$$

$$= \frac{10^{-5} + 10^{-3} + 10^{-5}}{3} = 3.4 \times 10^{-4}\ \text{cm/s}$$

$$K_V = \frac{H_1 + H_2 + H_3}{\frac{H_1}{K_1} + \frac{H_2}{K_2} + \frac{H_3}{K_3}} = \frac{3}{\frac{1}{10^{-5}} + \frac{1}{10^{-3}} + \frac{1}{10^{-5}}}$$

$\Rightarrow$ $$K_V = 1.49 \times 10^{-5}\ \text{cm/s}$$

$\therefore$ $$\frac{K_H}{K_V} = \frac{3.4 \times 10^{-4}}{1.49 \times 10^{-5}} = 22.82$$

52. (d)

$\because$ $$m_v = \frac{\Delta H}{H \cdot \Delta\sigma} = \frac{\epsilon_v}{\Delta\sigma}$$

$\therefore$ $$m_v = \frac{0.5}{18 \times (200 - 50)} = 1.852 \times 10^{-4}\ \text{m}^2/\text{kN}$$

$\therefore$ Constrained elastic modulus is the ratio of vertical stress to vertical strain in laterally confined condition (which is not same as Young's modulus). This constrained elastic modulus is given by,

$$E_c = \frac{1}{m_v} = \frac{1}{1.852 \times 10^{-4}} \simeq 5400\ \text{kPa}$$

53. (d)

Desiccated clay is very dry and has higher strength than saturated clay due to preconsolidation.

54. (c)

$\because$ $$h_2 = \sqrt{h_1 h_3}$$

$$= \sqrt{9 \times 3}\ \text{cm} = 3\sqrt{3}\ \text{cm}$$

$$= 5.2\ \text{cm}$$

56. (c)

The horizontal sheets of negligible thickness are assumed to be of infinite rigidity.

57. (a)

To avoid the air binding in rapid sand filter, the water should not be warm.

58. (c)

Thermal stratification has major effects on both oxygen concentration and nutrient supplies. When the lake is stratified, no mixing occurs between top and bottom layers. The hypolimnion receives no oxygen and the epilimnion receives no nutrients.

59. (b)

$$\text{Expanded depth of filter bed, } D_e = \frac{(1-n)D}{(1-n_e)}$$

$$D_e = \frac{(1-0.55)\times 0.8}{(1-0.65)} = 1.028 \text{ m}$$

$$\text{Head loss, } h_{Le} = D_e(1-n_e)(G-1) \qquad \text{[For expanded bed]}$$

$$= 1.028\ (1 - 0.65)\ (2.6 - 1)$$

$$= 0.575 \text{ m}$$

Alternatively,

Head loss can be computed as

$$h_L = D(1-n)(G-1) \qquad \text{[For unexpanded bed]}$$

$$= 0.8\ (1 - 0.55)\ (2.6 - 1)$$

$$= 0.576 \text{ m}$$

61. (c)

Sound intensity (or acoustic intensity) is the power carried by sound waves per unit area in the direction normal to area.

62. (d)

Hardness is due to the presence of multivalent cations like Mg^{2+} and Ca^{2+}.

$$\therefore \quad \text{Hardness as (mg/}l\text{ of } CaCO_3) = \frac{Mg^{2+}(\text{mg}/l)\times 50 \text{ mg/meq}}{\text{eq. wt. } Mg^{2+}} + \frac{Ca^{2+}(\text{mg}/l)\times 50 \text{ mg/meq}}{\text{eq. wt. } Ca^{2+}}$$

$$= \frac{9\times 50}{12.2} + \frac{48\times 50}{20}$$

$$= 156.9 \text{ mg}/l$$

$$\simeq 157 \text{ mg}/l\ CaCO_3$$

63. (a)

$$Q_{\text{design}} = \text{Maximum daily demand}$$

$$= 1.8 \times q \qquad [q = \text{Average daily demand}]$$

$$= 1.8 \times [10000 \times 150] = 27 \times 10^5\ l/\text{day}$$

$$= 112500\ l/\text{hr}$$

$$\therefore \quad f_r = \frac{Q_{design}}{\text{Area of filter}}$$

$$\text{Area of filter} = \frac{112500}{150} = 750 \text{ m}^2$$

$$\text{Area of each filter unit} = 150 \text{ m}^2$$

$\therefore$ Number of filters required $= \frac{750}{150} = 5$

64. (b)

Trihalomethanes (THM) are found to have been formed in chlorinated drinking waters, due to the interaction of chlorine with the organic substances like humic and fulvic acids present in water. Following chlorination, the formation of THM's is not instantaneous, but continues for an extended period of time.

65. (b)

Certain springs, sometimes discharge hot water due to the presence of sulphur in them. These hot springs usually emit sulphur mixed water (warm to boiling) and hence cannot be used for water supplies.

66. (d)

Dissolved oxygen content decreases with increase in temperature i.e. inversely proportional to temperature. Absorption by activated alumina process for fluoride removal is known as Prashanti Technology.

67. (c)

The following methods may be used for detecting the leakage of water from the underground water mains in distribution system:

(i) By direct observations
(ii) By using sounding rods
(iii) By plotting hydraulic gradient line
(iv) By using waste detecting meters

68. (b)

The following tests are used for measuring chlorine residuals :

1. DPD test
2. Ortholidine test
3. Chlorotex test
4. Starch iodide test

To measure the chloride concentration in the water sample, Mohr's test is used. It is also known as Argentrometric method.

69. (c)

Minimum chimney height $= h = 14(Q_s)^{1/3}$

where, Q_s = SO_2 emission in kg/hr

$\therefore \quad Q_s = \frac{4536 \text{ kg}}{7 \times 24} = 27 \text{ kg/hr}$

$\therefore \quad h = 14 \times (27)^{1/3}$

$= 14 \times 3$

$= 42 \text{ m}$

70. (b)

Due to inversion in the atmosphere, the upward movement of polluting smoke is stopped and hence the concentration increases below the inversion layer.

During inversion temperature of pollutants is less than air hence density is more, so they are not able to rise. Hence, concentrate below inversion layer.

71. (c)

Electrostatic precipitators remove particulate matter.

Venturi scrubbers are used to remove gaseous pollutants.

Muriatic acid is also known as Hydrochloric acid.

72. (b)

This is a case of confined aquifer. Using Theim's formula

$$Q = \frac{2\pi KH(S_1 - S_2)}{2.3\log_{10}\frac{r_2}{r_1}}$$

$$\Rightarrow \quad 0.2 = \frac{2\times 3.14\times K\times 15\times(5-3)}{2.3\times\log_{10}\left(\frac{50}{10}\right)}$$

$$\Rightarrow \quad K = 1.7077 \times 10^{-3} \text{ m/sec} \simeq 1.7 \times 10^{-3} \text{ m/sec}$$

73. (d)

$$\text{Temporal mean velocity, } G = \sqrt{\frac{P}{\mu V}}$$

Here, P = Power dissipated in kW

μ = Viscosity

V = Volume

$$\Rightarrow \quad 58 = \sqrt{\frac{750}{0.89\times 10^{-3}\times V}}$$

$$V = \frac{750}{0.89\times 10^{-3}\times 58^2}$$

$$V = 250.5 \text{ m}^3 \simeq 250 \text{ m}^3$$

74. (d)

A deep well is one which rests on an impervious 'mota' layer and draws supply from the pervious formation lying below the mota layer, through a bore hole made into the mota layer.

75. (a)

The difference between the actual free surface and the Dupuit's base pressure curve in a gravity well, arises due to the Dupuit's assumption of horizontal and radial flow. Whereas the actual prevailing velocity of the same magnitude have a downward vertical component so that greater saturated thickness is required for the same discharge.

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