BOOKLET SERIES

A

MADE EASY

Simulate the Real **ESE Prelims Exam** by

ANUBHAV
OPEN MOCK TEST

ESE 2026
Preliminary Exam

CIVIL ENGINEERING

FULL SYLLABUS TEST • PAPER-II

Answer Key

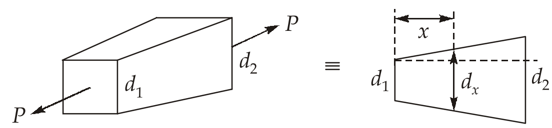
1.	(b)	26.	(c)	51.	(d)	76.	(c)	101.	(c)	126.	(c)
2.	(c)	27.	(c)	52.	(d)	77.	(c)	102.	(b)	127.	(c)
3.	(a)	28.	(b)	53.	(c)	78.	(b)	103.	(c)	128.	(c)
4.	(b)	29.	(b)	54.	(d)	79.	(b)	104.	(c)	129.	(c)
5.	(b)	30.	(a)	55.	(c)	80.	(d)	105.	(b)	130.	(c)
6.	(c)	31.	(c)	56.	(b)	81.	(c)	106.	(c)	131.	(d)
7.	(b)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

DETAILED EXPLANATIONS

1. (b)

Increased surface roughness causes stress concentration and reduces fatique strength.

2. (c)



$$d_x = d_1 + \left(\frac{d_2 - d_1}{L}\right)x = d_1 + kx$$

where $$k = \frac{d_2 - d_1}{L}$$

$\because$ $$d\Delta = \frac{P.dx}{A_x.E}$$

$\therefore$ $$\Delta = \int_0^L \frac{P \cdot dx}{d_x^2 \cdot E}$$

$\Rightarrow$ $$\Delta = \int_0^L \frac{P \cdot dx}{(d_1 + kx)^2 E} = -\frac{P}{E \cdot k}\left[\frac{1}{d_1 + kx}\right]_0^L$$

$\Rightarrow$ $$\Delta = -\frac{P}{E \cdot k}\left[\frac{1}{d_1 + \left(\frac{d_2 - d_1}{L}\right)x}\right]_0^L = -\frac{P}{E \cdot k}\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$$

$\Rightarrow$ $$\Delta = \frac{P}{E \cdot k}\left[\frac{1}{d_1} - \frac{1}{d_2}\right] = \frac{P}{E \times \left(\frac{d_2 - d_1}{L}\right)}\left[\frac{d_2 - d_1}{d_1 d_2}\right]$$

$\Rightarrow$ $$\Delta = \frac{PL}{Ed_1 d_2}$$

3. (a)

By principle of superposition,

$$\text{Slope at } A,\ \theta_A = \frac{M_A L}{3EI} + \frac{M_B L}{6EI}$$

$$\text{Slope at } B,\ \theta_B = \frac{M_A L}{6EI} + \frac{M_B L}{3EI}$$

Now, $$\frac{\theta_A}{\theta_B} = \frac{\frac{M_A L}{3EI} + \frac{M_B L}{6EI}}{\frac{M_A L}{6EI} + \frac{M_B L}{3EI}} = 1.5$$

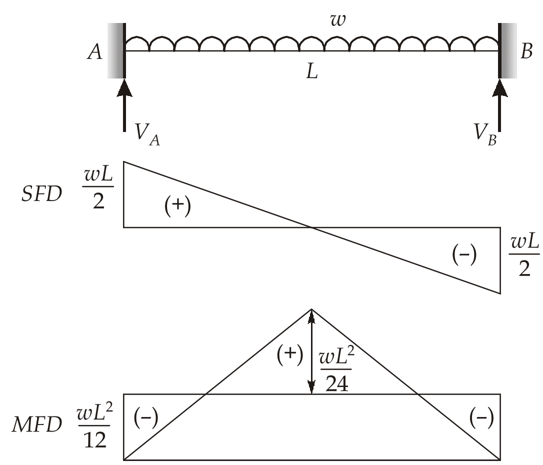
$\Rightarrow$ $$\frac{2M_A + M_B}{M_A + 2M_B} = 1.5$$

$$\Rightarrow \quad 2M_A + M_B = 1.5\,M_A + 3M_B$$

$$\Rightarrow \quad 0.5M_A = 2\,M_B$$

$$\Rightarrow \quad \frac{M_A}{M_B} = 4$$

4. (b)



$$V_A = V_B = \frac{wL}{2}$$

$$\text{Maximum moment, (at support)} = \frac{wL^2}{12} \text{ (Hogging)}$$

$$\therefore \quad \text{Ratio} = \frac{\text{Maximum BM}}{\text{Maximum SF}} = \frac{\frac{wL^2}{12}}{\frac{wL}{2}} = \frac{L}{6}$$

5. (b)

The radius of curvature of the bent wire, measured to the neutral axis of the cross section, is,

$$R = r + \frac{d}{2} \qquad \text{...(a)}$$

Using flexure formula, $\dfrac{\sigma}{y} = \dfrac{E}{R} = \dfrac{M}{I}$

Maximum bending stress, $\sigma_{max} = \dfrac{E}{R}y$

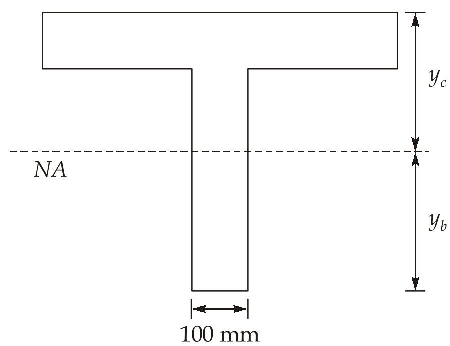
Here, $y = \dfrac{d}{2}$ and $R = r + \dfrac{d}{2}$

$$\therefore \quad \sigma_{max} = \frac{E}{r + \frac{d}{2}} \times \frac{d}{2} = \frac{Ed}{2r + d} = \frac{200 \times 10^3 \times 4}{2 \times 0.5 \times 1000 + 4}$$

So, $\sigma_{max} = 796.81 \text{ MPa} \simeq 797 \text{ MPa}$

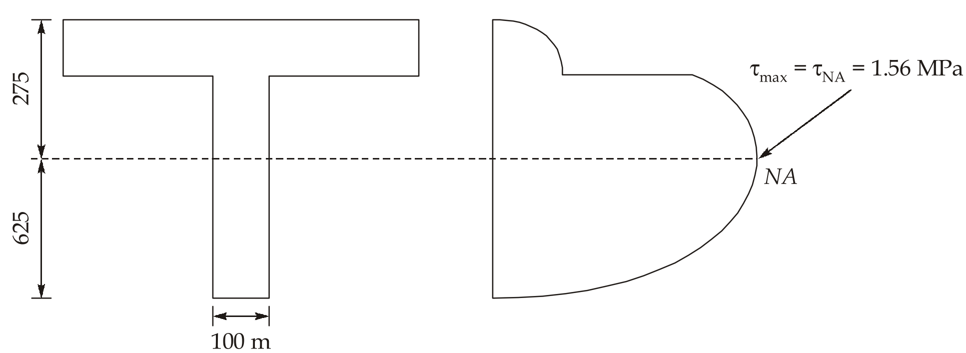
6. (c)

$$A_F = \text{Area of flange} = 8 \times 10^4 \text{ mm}^2$$
$$A_w = \text{Area of web} = 8 \times 10^4 \text{ mm}^2$$
$$y_c = \text{Depth of NA from top}$$
$$\therefore \quad y_c = \frac{800 \times 100 \times 50 + 800 \times 100 \times 500}{2 \times 800 \times 100}$$
$$\therefore \quad y_c = 275 \text{ mm}, \; y_b = 625 \text{ mm}$$

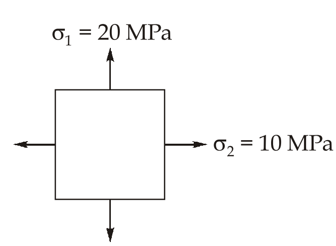


Maximum shear stress will occur at the neutral axis.

$$\therefore \quad \tau_{max} = \tau_{NA} = \frac{SA\bar{y}}{Ib} = \frac{100 \times 10^3 \times 625 \times 100 \times \frac{625}{2}}{1.25 \times 10^{10} \times 100}$$
$$\Rightarrow \quad \tau_{max} = 1.56 \text{ MPa}$$



7. (b)



$$\epsilon_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E}$$

$$\epsilon_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E}$$

$$\frac{\gamma_{max}}{2} = \frac{\epsilon_1 - \epsilon_2}{2}$$

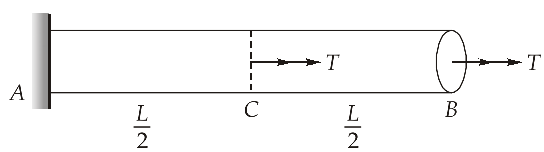
∴ $$\epsilon_1 = \frac{20}{E} - \frac{0.3 \times 10}{E} = \frac{17}{E}$$

Similarly $$\epsilon_2 = \frac{10}{E} - \frac{0.3 \times 20}{E} = \frac{4}{E}$$

∴ $$\gamma_{max} = \frac{17}{E} - \frac{4}{E} = \frac{13}{300 \times 10^3} = 4.33 \times 10^{-5}$$

8. (d)

9. (a)



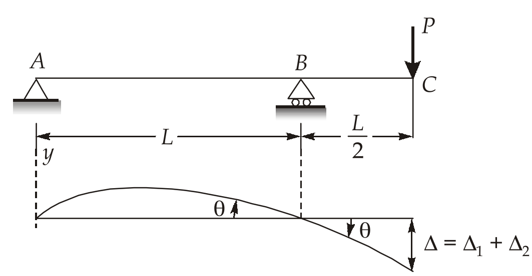
∴ Torque in the part $AC = 2T$

Torque in the part $CB = T$

∴ $$U = U_{AC} + U_{CB}$$

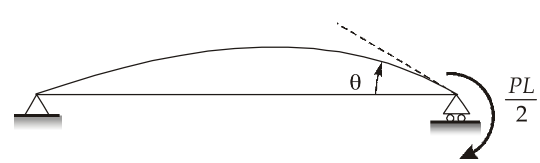
⇒ $$U = \frac{(2T)^2 \times \left(\frac{L}{2}\right)}{2GI_P} + \frac{T^2 \frac{L}{2}}{2GI_P} = \frac{5T^2 L}{4GI_P}$$

10. (b)



∴ $$\Delta_1 = \frac{P \times \left(\frac{L}{2}\right)^3}{3EI} = \frac{PL^3}{24EI}$$

and

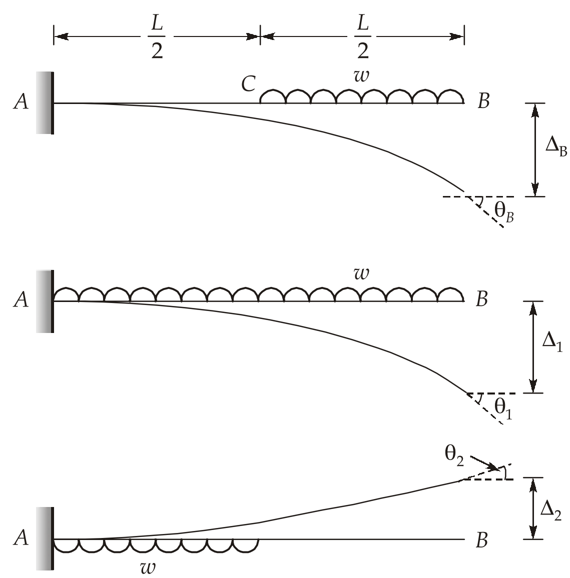


$$\therefore \quad \theta_B = \frac{\left(\frac{PL}{2}\right)\times L}{3EI} = \frac{PL^2}{6EI}$$

$$\therefore \quad \Delta_2 = \theta_B \times \frac{L}{2} = \frac{PL^3}{12EI}$$

$$\therefore \quad \Delta = \Delta_1 + \Delta_2 = \frac{PL^3}{8EI} \ (\downarrow)$$

11. (b)



$$\Delta_B = \Delta_1 - \Delta_2 = \frac{wL^4}{8EI} - \left[\frac{w\left(\frac{L}{2}\right)^4}{8EI} + \frac{w\left(\frac{L}{2}\right)^3}{6EI} \times \frac{L}{2}\right] = \frac{41\, wL^4}{384EI}$$

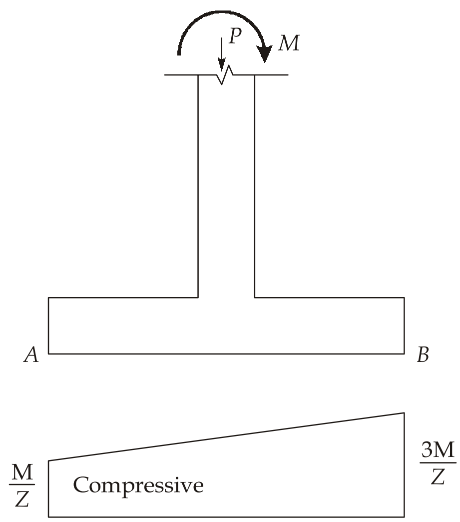
Similarly, $$\theta_B = \theta_1 - \theta_2 = \frac{wL^3}{6EI} - \frac{w\left(\frac{L}{2}\right)^3}{6EI} = \frac{7}{48}\frac{wL^3}{EI}$$

$$\therefore \quad \frac{\Delta_B}{\theta_B} = \left(\frac{41}{56}\right)L$$

12. (d)

Bearing pressure at base due to axial load = $\frac{P}{A}$

Stress at base due to moment = $\frac{M}{Z}$



Given, $$\frac{P}{A} = \frac{2M}{Z}$$

∴ $$\sigma_B = \frac{P}{A} + \frac{M}{Z} = \frac{3M}{Z} \text{ (compressive)}$$

$$\sigma_A = \frac{P}{A} - \frac{M}{Z} = \frac{M}{Z} \text{ (compressive)}$$

13. (b)

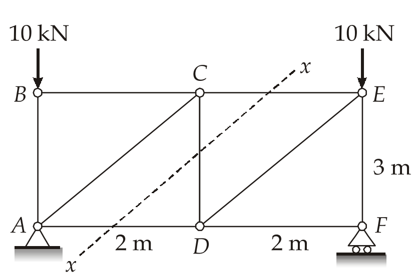
Hoop stress with radius R is given by $\sigma_n = \frac{B}{R^2} + A$

So, variation will be hyperbolic

14. (c)

Rigid joint does not mean that there will be no deformation in structure. Rigid joint can translate and rotate but it ensures compatibility of displacement of ends of connecting elements at joints.

15. (a)



$$R_A + R_F = 20 \quad \text{...(i)}$$

$$\Sigma M_F = 0$$

$\Rightarrow$ $$R_A = 10 \text{ kN} = R_F$$

Pass a section x-x,

$$\Sigma F_y = 0 \text{ (left to section } x\text{-}x)$$

$\therefore$ $$F_{CD} + 10 = 10$$

$\Rightarrow$ $$F_{CD} = 0$$

16. (c)

$$D_S = 3C - r$$

C = Number of cuts to make open frame

r = Number of equation or additional equation

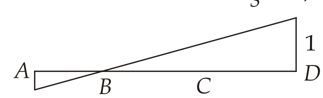
$$C = 1$$

$\therefore$ For hinge, $r = m - 1 = 2 - 1 = 1$

$\therefore$ $$D_S = 3 \times 1 - 3 = 3 - 3 = 0$$

17. (c)

Using Muller Breslau principle, structure is determinate $D_S = 0$, Lift at D by 1 and draw deflection line.



18. (c)

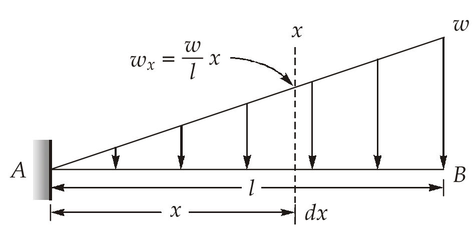
$$D_S = m + r - 2j$$

$$m = 13, r = 3, j = 8$$

$\therefore$ $$D_S = 13 + 3 - 2 \times 8 = 0$$

Hence, structure is stable and determinate.

19. (b)



$$EI\left(\frac{d^4y}{dx^4}\right) = -dF_x = w_x dx = +\frac{w}{l}x\,dx$$

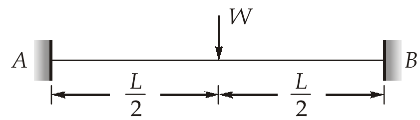
Integrate both sides between A and B

$$EI\left(\frac{d^3y}{dx^3}\right) = \frac{w}{l}\int_0^l x\,dx = +\frac{w}{l}\left(\frac{l^2}{2}\right)$$

$\Rightarrow$ $$EI\left(\frac{d^3y}{dx^3}\right) = +\frac{wl}{2}$$

$\therefore$ Shear force at fixed end $= \dfrac{wl}{2}$

20. (a)



Deflection at centre is given by

$$\delta = \frac{WL^3}{192EI},$$

$$\therefore \quad k = \text{stiffness} = \frac{192EI}{L^3}$$

So, $$\omega = \text{Natural frequency} = \sqrt{\frac{k}{m}}$$

$$\because \quad m = \frac{W}{g} \quad \therefore \quad \omega = \sqrt{\frac{192EI \times g}{L^3 \cdot W}} = 8\sqrt{\frac{3EIg}{L^3 \cdot W}}$$

21. (a)

Given: $$[K] = \frac{3EI}{4}\begin{bmatrix} 8 & -2 \\ -2 & 1 \end{bmatrix}$$

$$[\Delta] = \begin{bmatrix} \Delta_1 \\ \Delta_2 \end{bmatrix} = \begin{bmatrix} -\frac{\Delta}{EI} \\ 0 \end{bmatrix} = \text{Final displacement due to redundant force } [P]$$

$$[P] = \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}$$

$$\because \quad [P] = [K]\,[\Delta]$$

$$\Rightarrow \quad \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} = \frac{3EI}{4}\begin{bmatrix} 8 & -2 \\ -2 & 1 \end{bmatrix}\begin{bmatrix} -\frac{\Delta}{EI} \\ 0 \end{bmatrix}$$

$$\Rightarrow \quad \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} = \frac{3EI}{4}\begin{bmatrix} \frac{-8\Delta}{EI} \\ \frac{+2\Delta}{EI} \end{bmatrix}$$

$$\Rightarrow \quad P_1 = V_B = -\frac{8\Delta}{EI} \times \frac{3EI}{4} = -6\Delta$$

$$\therefore \quad V_B = 6\Delta$$

22. (c)

$$\text{Area of connected leg } (A_1) = \frac{A}{2}$$

$$\text{Area of outstanding leg } (A_2) = \frac{A}{2}$$

$$A_{net} = A_1 + kA_2$$

where,

$$k = \frac{3A_1}{3A_1 + A_2} = \frac{3 \times \frac{A}{2}}{3 \times \frac{A}{2} + \frac{A}{2}} = \frac{3}{4}$$

$$\therefore \quad A_{net} = \frac{A}{2} + \frac{3}{4} \times \frac{A}{2} = 0.875\,A$$

23. (b)

Effective length of struts

S. No.	Type	Sections	Effective length In the plane of the gusset	Effective length perpendicular to the gusset
1.	Continuous	Single or double angle	0.7 L to 1.00 L	1.00 L
2.	Discontinuous	Single-angle connected with one bolt	1.00 L	1.00 L
3.	Discontinuous	Single-angle connected with more than one bolt or welded	0.85 L	1.00 L
4.	Discontinuous	Double-angles placed back to back on opposite sides of gusset plate	0.70 L to 0.85 L	1.00 L
5.	Discontinuous	Double-angles placed back to back on same side of gusset plate	0.70 L to 0.85 L	1.00 L

24. (d)

The maximum spacing of lacing bars should be such that the minimum slenderness ratio of the component member i.e. C/r_{yy} is not greater than 50 or 0.7 times the slenderness ratio of the member as a whole, whichever is less, where C is the distance between the centres of connection of the lacing bars to each component.

(i) $$\frac{C}{r_{yy}} \leq 50$$

$$\Rightarrow \quad C \leq 50\,r_{yy} = 50 \times 10 = 500 \text{ mm}$$

$$\therefore \quad C \leq 500 \text{ mm}$$

(ii) $$\frac{C}{r_{yy}} \leq 0.7 \times \text{Overall slenderness ratio}$$

$$\Rightarrow \quad C \leq 0.7 \times 40 \times 10 = 280 \text{ mm}$$

$$\therefore \quad C = 280 \text{ mm}$$

25. (c)

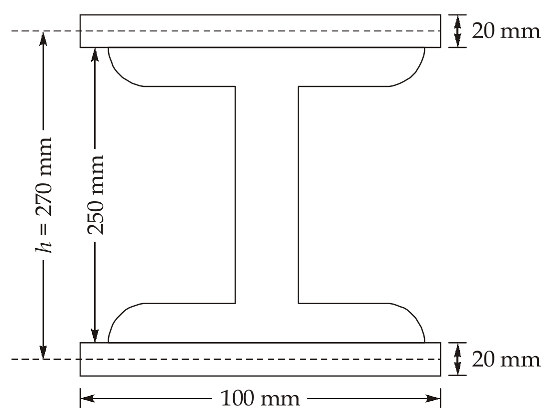
Enhanced moment carrying capacity (M).

$$M = (z_p)_{\text{Plate}} \times \frac{f_y}{1.1}$$

$$(z_p)_{\text{Plate}} = A_p \cdot h \text{ (where, } A_p = \text{Area of plate)}$$

$$A_p = 100 \times 20 = 2000 \text{ mm}^2$$

$$h = 250 + 20 = 270 \text{ mm}$$



$\therefore$
$$M = 2000 \times 270 \times \frac{250}{1.1} \times 10^{-6} \, kNm$$

$\Rightarrow$
$$M = 122.72 \text{ kNm} \simeq 122 \text{ kNm (say)}$$

26. (c)

$$f_{\max} = \frac{M_{\max}}{z}$$

But,
$$M_{\max} = \frac{wl^2}{2} = \frac{20 \times 3^2}{2} = 90 \text{ kN-m}$$

$\therefore$
$$z = \frac{I_{xx}}{y} = \frac{1696.6 \times 10^4}{200/2} = 169660 \text{ mm}^3$$

$\therefore$
$$f_{\max} = \frac{90 \times 10^6}{169660} = 530.47 \text{ N/mm}^2$$

27. (c)

As per Cl.10.5.5.2 of IS : 800-2007, the clear spacing between the effective lengths of intermittent fillet welds shall not exceed 12 and 16 times the thickness of thinner plate joined, for compression and tension joint respectively, and in no case be more than 200 mm.

28. (b)

Tensile yield stregth = 800 × 0.8 = 640 MPa (If d < 16 mm)

Tensile properties of bolts in steel construction

Grade/Classification	Properties		
	Yield Stress f_y MPa (min)	Ultimate Tensile Stress Sub MPa (min)	Elongation Percentage (min)
3.6	180	330	25
4.6	240	400	22
4.8	320	420	14
5.6	300	500	20
5.8	400	520	10
6.8	480	600	8
8.8 (d < 16 mm)	640	800	12
(d > 16 mm)	660	830	12
9.8	720	900	10
10.9	940	1040	9
12.9	1100	1220	8

29. (b)

Given: $k_2 = 0.8,\quad k_3 = 1.2,\quad k_4 = 1.0$

$p = 540\ \text{N/m}^2,\quad V_b = 45\ \text{m/sec}$

We know, $p = 0.6\ V_z^2$

$$\therefore \quad V_z = \sqrt{\frac{540}{0.6}} = \sqrt{900} = 30\ \text{m/s}$$

But $V_z = k_1 k_2 k_3 k_4 V_b$

$$\therefore \quad k_1 = \text{risk coefficient} = \frac{30}{45 \times 0.8 \times 1.2 \times 1} = 0.694$$

$$\Rightarrow \quad k_1 \simeq 0.7$$

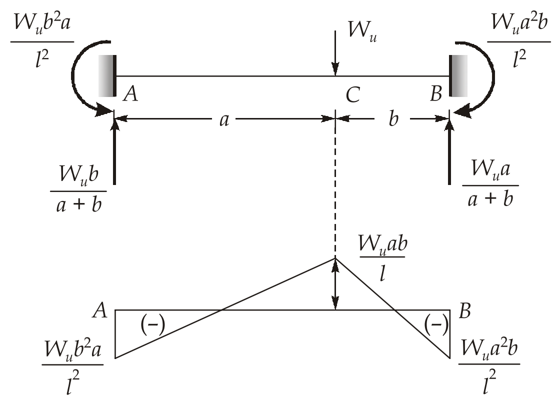
30. (a)

Gantry girders are unique in themselves. First, it is different from usual beams in buildings. It is generally laterally unsupported except at the columns. Second, it must be analysed for unsymmetrical bending because of lateral thrust from the starting and stopping of the crab. Third, it is subjected to longitudinal load due to starting and stopping of the crane bridge itself; and the fourth, these are subjected to the vertical load , lateral load, longitudinal load and impact load.

Gantry girders are subjected to vertical load or longitudinal load at a time not all load act simultaneously on it. Therefore design of gantry girder predominantly is not design for gravity load, however it must be considered along with other loads.

31. (c)

32. (b)



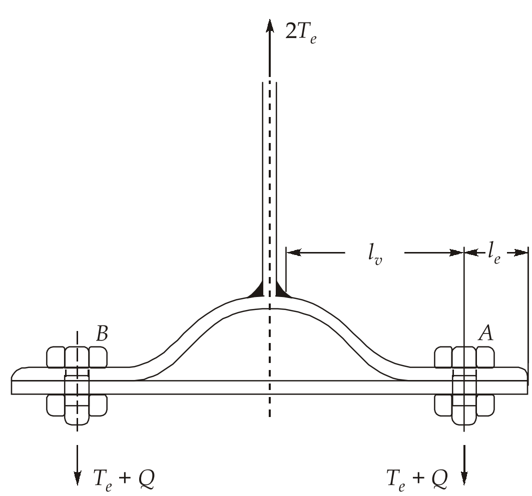
$$BM_{max\text{-}B} = \frac{W_u a^2 b}{l^2} \text{ (at } B)$$

$$BM_{max\text{-}C} = \frac{W_u ab}{l} \text{ (at } C)$$

$$BM_{max\text{-}A} = \frac{W_u ab^2}{l^2} \text{ (at } A) < \frac{W_u a^2 b}{l^2}$$

∴ First plastic hinge will be developed at B then, C and then at A.

33. (a)



As per IS 800:2007 (Cl. 10.4.7)

The prying force Q is given by

$$Q = \frac{l_v}{2l_e}\left[T_e - \frac{\beta\eta f_o b_e t^4}{27 l_e l_v^2}\right] \simeq \frac{T_e l_v}{2l_e}$$

where;

l_v = distance from bolt centre line to the toe of the fillet weld.

l_e = distance between prying force and bolt centre line and in minimm of either the end distance or the value given by

$$1.1t\sqrt{\beta\frac{f_o}{f_y}}$$

β = 1 for pretensioned bolt and 2 for non-pretensioned bolt
η = 1.5 (for LSM)
b_e = effective width of flange per pair of bolts
f_o = proof stress
t = thickness of end plate

34. (c)

Welds and HSFG bolts can share design action because both behave elastically with minimal slip, whereas rivets and ordinary bolts involve slip/bearing and hence cannot reliably share load.

35. (a)

If sloping roof with slope > 10°

then, Live load - 0.75 – 0.02 (Slope angle – 10°)

$\therefore$ w_L = 0.75 – 0.02 (16 – 10)

= 0.63 kN/m^2

36. (a)

Higher strain capacity in flexure does not mean higher stress. Limit state models stop before post-failure behaviour, not after it.

37. (c)

Mild steel, continuous slab → 40

HYSD steel, continuous slab → 0.8 × 40 = 32

$\therefore$ Required ratio = $\frac{40}{32}$ = 40 : 32

38. (c)

Minimum tensile strain in steel = $0.002 + \frac{0.87 f_y}{E_S}$

$= 0.002 + 0.87 \times 415/ (2 \times 10^5)$

$= 0.0038$

39. (a)

Statement 4 is incorrect because moment redistribution does not automatically ensure ductility. As per IS 456 : 2000, redistribution is permitted only when the section has adequate rotation capacity, which depends on the section being under-reinforced and properly detailed.

40. (c)

When the depth of the web exceeds 500 mm, longitudinal distribution reinforcement not less than 0.05 percent of the area of the web shall be provided on each face. The spacing of the individual bars of such reinforcement shall not exceed 200 mm.

41. (c)

For members subjected to axial compression the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor:

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \text{ but not exceeding 1.5}$$

where P_u = Axial compressive force in Newtons,

A_g = Gross area of the concrete section in mm², and

f_{ck} = Characteristic compressive strength of concrete.

$$\therefore \quad \delta = \text{Minimum}\begin{cases} 1 + \dfrac{3 \times 2800 \times 1000}{20 \times 300 \times 700} = 3 \\ 1.5 \end{cases}$$

$$\therefore \quad \delta = 1.5$$

42. (b)

According to Clause 39.4.1 of IS 456: 2000,

The ratio of volume of helical reinforcement to the volume of core shall not be less than

$$0.36 \frac{f_{ck}}{f_y}\left[\frac{A_g}{A_c} - 1\right]$$

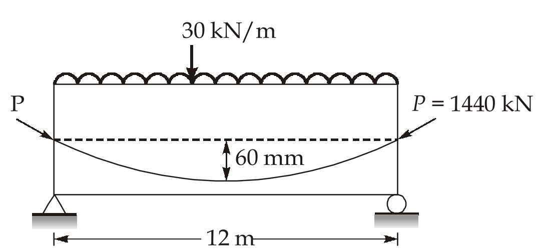
For, initial condition f_{ck_1} = 20 MPa, f_{y_1} = 415 MPa

For, final condition f_{ck_2} = 30 MPa, f_{y_2} = 500 MPa

$$\therefore \quad \text{Percentage change} = \frac{\dfrac{30}{500} - \dfrac{20}{415}}{\dfrac{20}{415}} \times 100 = \left(\frac{30 \times 415}{20 \times 500} - 1\right) \times 100$$

$$= 24.5\%$$

43. (d)



Intensity of equivalent load due to parabolic cable.

$$w_p = \frac{8Ph}{l^2} = \frac{8 \times 1440 \times 0.06}{12^2} = 4.8 \text{ kN/m}$$

So, net downward UDL w_{net} = 30 – 4.8 = 25.2 kN/m

$$\text{Maximum shear force at support} = \frac{25.2 \times 12}{2}$$

$$= 151.2 \text{ kN}$$

44. (a)

$$b = \sqrt{R^2 + T^2}$$

$\therefore$ $$b = \sqrt{160^2 + 260^2} = \sqrt{25600 + 67600}$$

$\Rightarrow$ $$b = \sqrt{93200} = 305.3 \text{ mm}$$

45. (c)

Earnest money is an assurance or guarantee on the part of the contractor to keep open the offer for consideration and to confirm his intention to take up the work if accepted in his favour for execution as per terms and conditions in the tender.

The security money is refunded to the contractor after satisfactory completion of the whole work within a specified time limit, usually after one rainy season or 6 months to one year of the completion of the work whichever is later.

46. (b)

If the resource availability is limited, it cannot meet period by period variation. In this case, the project duration may be extended to the minimum possible such that the demand actually agrees with the availability. This is called resource levelling.

Total project cost depends upon direct and indirect project cost. Therefore project cost may increase or decrease by reducing critical path.

47. (c)

Given: 9 activities on critical path

$\therefore$ $$\sigma_{cp} = \sqrt{\sigma_1^2 + \sigma_2^2 + ... + \sigma_9^2}$$

where, σ_1, σ_2 ....., σ_n are standard deviations of activities 1 to 9.

$\therefore$ $$\sigma_{cp} = \sqrt{9 \times 3^2} = 9$$

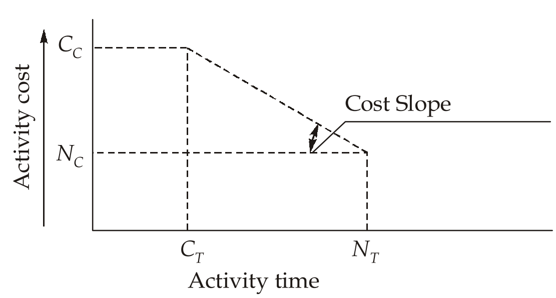
$\because$ Expected project duration, μ_{cp} = 45 days

$\therefore$ Probable range = $\mu_{cp} - 3\sigma_{cp}$ to $\mu_{cp} + 3\,\sigma_{cp}$

$\therefore$ = 45 – 3 × 9 to 45 + 3 × 9

= 18 to 72 days

48. (b)



$$C_S = \frac{C_C - N_C}{N_T - C_T}$$

49. (b)

Item rate contract is also known as unit price contract or schedule contract. A contractor undertakes the execution of work on an item rate basis. He is required to quote rate for individual item of work on the basis of schedule of quantities (i.e. bill of quantities) furnished by the department. The amount to be received by the contractor, depends upon the quantities of work actually performed. The payment to the contractor is made on the basis of the detailed measurements of different items of work actually executed by him.

50. (c)

51. (d)

Given, initial cost = Rs. 200000

$$n = 5 \text{ years}, \quad FDDB = \frac{2}{n},$$

$$\therefore \quad FDDB = \frac{2}{5} = 0.4$$

Book value at the end of second year = $B_2 = C_i\,(1 - FDDB)^2$

$$\Rightarrow \quad B_2 = 2 \times 10^5\,(1 - 0.4)^2 = 2 \times 10^5 \times 0.36 = 72000$$

∴ Depreciation at the end of 2nd year or starting of 3rd year = $C_i - B_2$ = 200000 – 72000 = Rs. 128000

52. (d)

$$\text{Total project cost} = 4 \times 10^5 + 50000 = \text{Rs. } 450{,}000$$

$$\text{Bid price} = \text{Project cost + Mark-up cost}$$

Here, $\text{Markup cost} = 0.1 \times \text{Bid price}$

$$\therefore \quad \text{Bid price} = 4.5 \times 10^5 + 0.1 \times \text{Bid price}$$

$$\Rightarrow \quad \text{Bid price} = 4.95 \times 10^5 = \text{Rs. } 495000$$

53. (c)

Dehydration (400-650°C) : This is also known as water smoking stage. During dehydration:

1. The water which has been retained in the pores of the clay after drying is driven off and the clay loses its plasticity.
2. Some of the carbonaceous matter is burnt.
3. A portion of sulphur is distilled from pyrites.
4. Hydrous minerals like ferric hydroxide are dehydrated.
5. The carbonate minerals are more or less decarbonated.

54. (d)

The properties of the sedimentary rocks vary considerably depending upon the nature of the sediment and type of bond between the sediment and grains. Usually, the rocks are well stratified and show well defined bedding planes.

The rocks are soft and can be easily split up along the bedding as well as normal planes.

The examples of sedimentary rocks resulting from the precipitation of salts in drying water basin (chemical deposits) are gypsum, anhydrite, magnesite, dolomite lime tufas.

Sedimentary rocks resulting from the accumulation of plant or animal remains (organogenous rocks) are limestone, shale, chalk, diatomite and tripoli.

The examples of rocks resulting from the deterioration of massive magmatic or sedimentary rocks (fragmental rocks) are sandstone, sand, gravel, carbonate conglomerate and breccia.

55. (c)

Carbonaceous materials in the form of bituminous matter or carbon greatly affect the colour of raw clay. Unless proper precaution is taken to effect complete removal of such matter by oxidation, the brick is likely to have a black core.

56. (b)

57. (c)

58. (d)

The stiffening of cement without strength development is caused because of C_3A.

59. (c)

The rate of heat evolution of the compounds if equal amount of each is considered will be in the following descending order:

$$C_3A, C_3S, C_4AF, C_2S$$

The rate of hydration is increased by an increase in fineness of cement. However, total heat evolved is the same. The rate of hydration of the principal compounds is shown in and will be in the following descending order:

$$C_4AF, C_3A, C_3S, C_2S$$

60. (a)

$$\text{Maturity} = (27 - (-11)) \times 12 \times 5 + (24 - (-11)) \times 12 \times 5 \text{ °C hours.}$$
$$= 4380 \text{ °C hours.}$$

61. (d)

1. Pycnometer is used for determining specific gravity for aggregates of size smaller than 10 mm.
2. Ten Per Cent Fines Test (IS: 2386 (Part IV):
   The ten per cent fines value gives a measure of the resistance of an aggregate to crushing.

62. (a)

Organic matter in water for making concrete should not be more than 200 ppm.

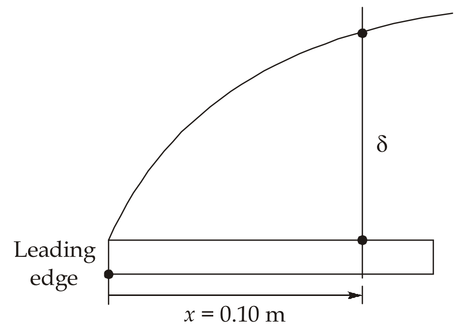
63. (a)

Volume of coarse aggregates needed for the preparation of 1 m^3 of concrete = 4 × 1.54/(1 + 2 + 4) = 0.88 m^3

64. (b)

Air vessels reduce acceleration head and friction losses, allow higher operating speed, and minimize pressure fluctuations; however, they do not ensure uniform discharge in the suction pipe.

65. (d)



Rate of growth of boundary layer is, $\dfrac{\delta}{x} = \dfrac{5}{\sqrt{R_e}}$

$$R_e = \frac{\rho v x}{\mu} = \frac{10^3 \times 3 \times 0.10}{0.001} = 3 \times 10^5$$

$$\therefore \quad \frac{\delta}{0.1} = \frac{5}{\sqrt{3 \times 10^5}}$$

$$\Rightarrow \quad \delta = 9.13 \times 10^{-4} \text{ m} = 0.913 \text{ mm} \simeq 0.90 \text{ mm (say)}$$

66. (c)

$$u = \frac{-\partial \psi}{\partial y}, \; v = \frac{+\partial \psi}{\partial x}$$

$$\partial \psi = -2\, \partial y$$

$$\therefore \quad \psi = -2y + f(x)$$

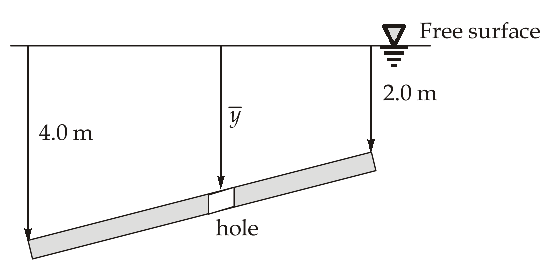
$$\therefore \quad v = \frac{\partial[-2y + f(x)]}{\partial x} = \frac{\partial}{\partial x}[f(x)]$$

Integrating, $\int \partial f(x) = \int 5 \partial x$

$$\Rightarrow \quad f(x) = 5x$$

$$\therefore \quad \psi = -2y + 5x$$

67. (a)



Hydrostatic force, $F = \rho g \overline{y} A$

$$= 1.8 \times 10^3 \times 10 \times \left(\frac{2+4}{2}\right)\left[\frac{\pi}{4} \times \left(2^2 - 0.5^2\right)\right]$$

$$= 159.04 \times 10^3 \text{ N}$$

$$= 159.04 \text{ kN} \simeq 159 \text{ kN}$$

68. (d)

69. (c)

70. (b)

71. (b)

72. (a)

Device		Typical C_d
Triangular (V-notch) weir	≈	0.52
Sharp-edged orifice	≈	0.60
Broad-crested weir	≈	0.85
Venturimeter	≈	0.98

73. (b)

74. (c)

Boundary layer separation:

- Separation is caused by adverse pressure gradient
- Separation creates wake so large pressure drag.

75. (c)

$$\text{Water treated per day} = 25 \times 10^6\ l/\text{d}$$
$$\text{Chlorine consumed per day} = 10\ \text{kg/d}$$
$$\text{Chlorine used per litre of water} = \frac{10 \times 10^6\ \text{mg/d}}{25 \times 10^6\ l/\text{d}} = 0.4\ \text{mg}/l$$
$$\text{Chlorine demand} = \text{Chlorine used} - \text{Residual chlorine} = 0.40 - 0.20 = 0.20\ \text{mg}/l$$

76. (c)

As filter is designed for maximum daily demand,

$$\text{Maximum daily demand} = 1.5 \times \text{Average daily demand} = 1.5 \times 150 \times 10^5\ l/\text{d} = 22.5 \times 10^6\ l/\text{d}$$
$$\text{Area of filters} = \frac{\text{Maximum daily demand}}{\text{Filtration rate}} = \frac{22.5 \times 10^6}{24 \times 4500}\ \text{m}^2 = 208.33\ \text{m}^2$$
$$\therefore \quad \text{Number of filter units} = \frac{208.33}{50} = 4.16 \approx 5$$

77. (c)

Rate of SO_2 emission:

Coal burnt per hour = 8 tonnes = 8000 kg

Sulphur produced per hour = 0.045 × 8000

= 360 kg

$$S + O_2 \longrightarrow SO_2$$

As 1 mole sulphur (32 grams) produces 1 mole of SO_2 (64 grams),

∴ 360 kg of sulphur will produce = $\frac{64}{32} \times 360 \text{ kg } SO_2$

= 720 kg SO_2 per hour

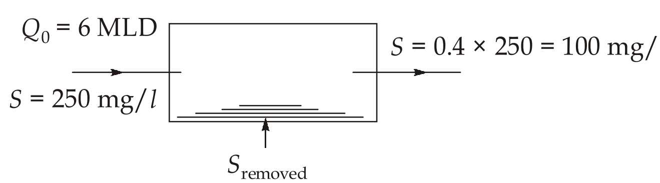
For slightly unstable atmosphere, location of maximum ground level concentration,

x_{max} = 10 h

where, h = height of stack = 90 m

∴ x_{max} = 10 × 90 = 900 m

78. (b)



Suspended solids removed = $(250 - 100)\frac{mg}{l} \times 6 \times 10^6 \frac{l}{d}$

= 900 kg/d

As sludge contains 90% moisture which means sludge has 10 kg solids and 90 kg water

∵ 10 kg solids have 90 kg water

∴ 900 kg solids have $\frac{90}{10} \times 900$ kg water = 8100 kg water

∴ Weight of sludge produced = 900 + 8100 = 9000 kg

∴ Volume of sludge produced = $\frac{9000}{1050} \text{m}^3$ = 8.57 m^3

79. (b)

$$\text{Recirculation, } R = \frac{Q_r}{Q} = \frac{X_t}{\frac{10^6}{SVI} - X_t}$$

$$SVI = \frac{1000\, V_s}{X_t}\left(\frac{ml}{g}\right) = \frac{1000 \times 200}{2000}\frac{ml}{g}$$

= 100 ml/g

$$\therefore \quad R = \frac{2000}{\frac{10^6}{100} - 2000} = 0.25$$

80. (d)

- Bio-filters are shallow filters (1.2 - 1.5 m depth) and improve treatment efficiency by recirculating a portion of the filter effluent to the primary clarifier, allowing a second passage through the filter.
- Accelo-filters (Inflico Inc.) employ direct recirculation of unsettled filter effluent from the bottom of the filter back to the top through a two-arm distributor, enhancing oxygen transfer and biofilm activity
- Aero-filters (Yeomans Bros.) are distinguished by the use of compressed air blown through the filter bed during operation, providing better aeration and eliminating the need for heavy recirculation.

81. (c)

A sharp-crested weir is primarily a flow-measuring device, not a velocity-control device. It does not maintain constant velocity in grit chambers under varying flow conditions.

82. (c)

As per IS: 3307-1977

S.N.	Type of load present	Prescribed limit
1	Total concentration of solids (inorganic)	$\le$ 2100 ppm
2	Percentage of sodium with respect to total content of sodium, calcium, magnesium and potassium	$\le$ 60%
3.	Boron	$\le$ 2 ppm
4.	pH value of sewage	5.5-9.0
5.	BOD	$\le$ 500

83. (b)

- Drop manhole safely connects a branch sewer at higher level to a main sewer at lower level.
- Manhole is used for inspection, cleaning and maintenance of sewers.
- Lamphole is provided where manholes are difficult, mainly for inspection, ventilation and flushing.
- Flushing tank creates artificial self-cleansing velocity in flat or dead-end sewers.

84. (d)

Dupuit's theory assumes horizontal flow throughout the aquifer depth and not vertical flow.

85. (a)

Solute stabilization involves chemical conversion without removal from water.

86. (b)

For a train approaching a station, the order is: Outer signal (first warning), then Home signal (entry into station), followed by Starter (departure authority), and finally Advance Starter (clears station limits).

87. (c)

$$\text{Thermal force, } P = (E\alpha\,\Delta T) \times A$$
$$= 2 \times 10^6 \times 12 \times 10^{-6} \times 30 \times 66$$
$$= 47520 \text{ kg}$$

Length required to overcome thermal stress, $L_T = \dfrac{P}{\text{Resistance}}$

$$\Rightarrow \quad L_T = \frac{47520 \text{ kg}}{0.7 \text{ kg/m}}$$

$$\Rightarrow \quad L_T = 67885.7\text{m} = 67.885 \text{ km}$$

Minimum length required to prevent creep = $2 \times L_T$

$$= 135.77 \text{ km} \simeq 136 \text{ km}$$

88. (b)

In the normal take-off case, the basic runway length is taken as 115% of the lift-off distance required to reach a height of 10.5 m, and the clearway length shall not exceed half of the take-off distance.

89. (b)

Effects of driving tunnels through stratified rock formations:

- Driving along the dip is dangerous due to sliding of strata.
- Fault zones are weak, fractured, and water-bearing.
- Driving along strike (slip) offers more uniform and stable conditions.

90. (c)

Wreck buoys are special purpose navigation buoys used to mark the position of sunken vessels or wrecks that poses danger to navigation. They are deployed both in harbours and in open sea to warn ships and to identify the exact location of the wreck, ensuring safe navigation.

91. (c)

- Theoretical methods are based on mathematical analysis of stresses and strains in pavement layers (for example: Boussinesq, Westergaard, Burmister).
- North Dakota cone method is an empirical method.

92. (b)

Wider shoulders increase freedom of movement, narrow shoulders reduce capacity.

93. (b)

Average skid resistance, $f = 0.7$

Skid resistance, $$f' = \frac{u^2}{2gL} = \frac{\left(\frac{5}{18} \times 60\right)^2}{2 \times 10 \times 22}$$
$$= 0.6313$$

$$\therefore \quad \text{Brake efficiency} = \frac{f'}{f} \times 100 = \frac{0.6313}{0.70} \times 100$$
$$\simeq 90\%$$

94. (d)

For cement concrete road, in region of heavy rainfall, camber is provided at a rate of 1 in 50 i.e. 2%.

$$\text{By straight line relation } y = \frac{W}{2n} = \frac{7}{2}\times\frac{1}{50}\times 100 \text{ cm}$$

$$\text{Camber} = 7 \text{ cm}$$

95. (b)

$$\text{Total thickness of pavement, } t = \left[\frac{1.75P}{CBR} - \frac{A}{\pi}\right]^{1/2}$$

$$\text{Contact area, } A = \frac{\text{Load}}{\text{Tyre pressure}} = \frac{4200}{7}$$

$$= 600 \text{ cm}^2$$

$$t = \left[\frac{1.75\times 4200}{4} - \frac{600}{\pi}\right]^{1/2}$$

$$\Rightarrow \quad t = [1837.5 - 190.91]^{1/2}$$

$$\Rightarrow \quad t = 40.58 \text{ cm}$$

96. (b)

Distance of occurance of maximum stress from the point of load is given as, $x = 2.58\sqrt{a.L}$

a = Radius of contact area in cm = 12

L = Radius of relative stiffness in cm = 75

$$\therefore \quad x = 2.58\sqrt{12\times 75}$$

$$\Rightarrow \quad x = 77.40 \text{ cm}$$

97. (d)

As per IRC, minimum value of transition curve is,

$$L_S = 2.7\frac{V^2}{R} = 2.7\times\frac{80\times 80}{600} = 28.8 \text{ m}$$

$$\text{Shift,} \quad S = \frac{L_S^2}{24R} = \frac{28.8^2}{24\times 600} = 0.0576 \text{ m} \,;\, 5.76 \text{ cm}$$

98. (b)

$$\text{Area of steel per meter length,} \quad A_s = \frac{(1\,bh)\,f\times\gamma_c}{f_s}$$

$$\Rightarrow \quad A_s = \frac{(1\times 3.75\times 0.20)\times 1.5\times 2400}{1500}$$

$$\Rightarrow \quad A_s = 1.8 \text{ cm}^2 \text{ per m length}$$

99. (c)

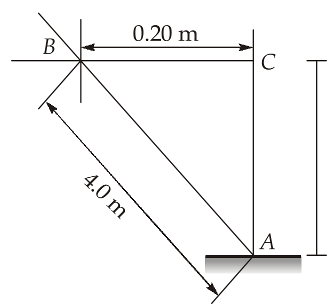
$$\text{Length of } NH = \frac{\text{Area of district in km}^2}{50} = \frac{15000 \text{ km}^2}{50} = 300 \text{ km}$$

$$\text{Length of } SH = Max\begin{cases} 62.5 \times \text{Number of towns} - \text{Length of NH.} \\ \dfrac{\text{Area of district in km}^2}{25} \end{cases}$$

$$= Max\begin{cases} 62.5 \times 20 - 300 \\ \dfrac{15000}{25} \end{cases} = Max\begin{cases} 950 \text{ km} \\ 600 \text{ km} \end{cases} = 950 \text{ km}$$

$\therefore$ Total length of NH and SH = 300 + 950 = 1250 km

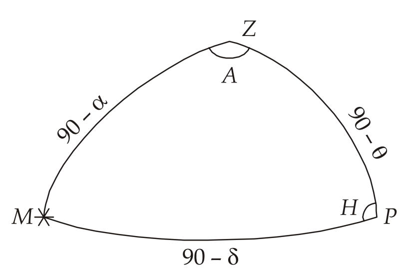
100. (c)



Correct staff reading, $AC = \sqrt{AB^2 - BC^2} = \sqrt{4^2 - 0.2^2}$

$\Rightarrow$ AC = 3.995 m

101. (c)



α = Altitude

θ = Latitude

δ = Declination

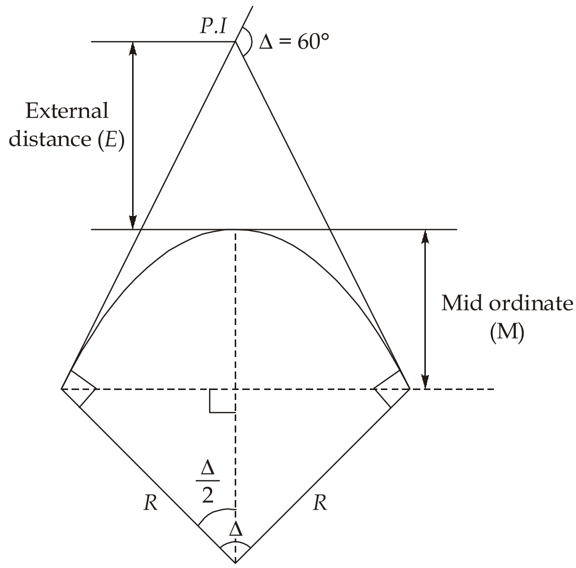
$$\cos H = \frac{\sin\alpha}{\cos\theta\cos\delta} - \tan\theta\tan\delta$$

$$\Rightarrow \quad \cos H = \frac{\sin 25^\circ}{\cos 40^\circ \cos 30^\circ} - \tan 40^\circ \cdot \tan 30^\circ$$

$\Rightarrow$ $\cos H = 0.1525 \simeq 0.15$

$\therefore$ $H = \cos^{-1}(0.15) = 81.37^\circ$

102. (b)



$$\text{External distance } (E) = R\sec\frac{\Delta}{2} - R$$

$$\text{Radius of curve, } R = 15 \times 30 = 450 \text{ m}$$

$$\therefore \quad E = 450 \sec 30° - 450$$

$$= 69.615 \text{ m}$$

$$= 2 \text{ chains } 48.1 \text{ links} \simeq 2 \text{ chains } 48 \text{ links}$$

103. (c)

Difference in elevation between two points is

$$\Delta h = \left(\frac{p_2 - p_1}{p_1 p_2}\right) \times Bf = \frac{50-48}{50\times 48}\times 300 \times 150$$

$$= 37.5 \text{ m}$$

104. (c)

In EDM, the distance between station 'D' is displayed

$$2D = n\lambda + \Delta\lambda$$

Phase comparison,

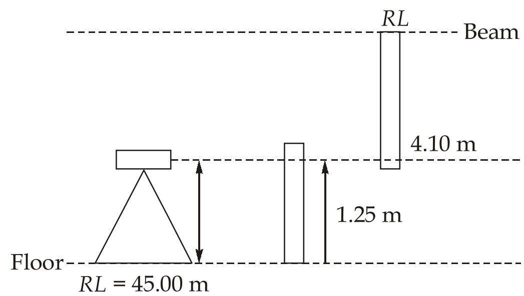
$$\Delta\lambda = \frac{\theta_2 - \theta_1}{360°}\times\lambda$$

$$\therefore \quad 2 \times D = 5 \times 20 + \frac{180° - 60°}{360°}\times 20$$

$$\Rightarrow \quad 2D = 106.66 \text{ m}$$

$$\Rightarrow \quad D = 53.33 \text{ m}$$

105. (b)



Reduced level of beam = RL of floor + HI + Staff intercept
= 45 + 1.25 + 4.10
= 50.35 m

106. (c)

107. (b)

Instrument and their uses:

- Pantagraph → Map reproduction (scaling) and uses principle of similar triangles
- Sextant → Angle measurement by reflection
- Ceylon Ghat Tracer → Gradient setting in ghats
- Burel Hand Level → Rough/approximate levelling

108. (c)

Telescope should preferably be anallactic to eliminate additive constant.

109. (b)

Declination is zero at equinoxes, not at solstices.

110. (c)

The ratio of a given volume change in a soil, expressed as percentage of the dry volume, to the corresponding change in water content is called shrinkage ratio. The ratio of a given volume change in a soil, expressed as percentage of the dry volume is known as volumetric shrinkage.

111. (a)

Given: $w_L = 40\%$
$w_p = 32\%$
$w_n = 36\%$

If 50% > w_L > 35%, soil is classified as medium compressible.

Plasticity index (I_p) = $w_L - w_p = 8\%$

∴ Soil plasticity is low

$$\text{Activity number} = \frac{I_p}{\%c} = \frac{8}{8} = 1.0$$

∴ Based on activity number soil is classified as normal.

Consistency index (CI)	Liquidity index (LI)	Consistency
100 - 0.75	0.00 - 0.25	Stiff
0.75 - 0.50	0.25 - 0.50	Medium soft
0.50 - 0.25	0.50 - 0.75	Soft
0.25 - 0.00	0.75 - 1.00	Very soft

Activity number	Classification
0.75	Inactive
0.75 - 1.25	Normal
> 1.25	Active

∴ Soil is normal.

Liquid limit	Compressibility
0 - 35%	Low
35-50%	Medium
> 50%	High

∴ Soil is of medium compressibility.

Plasticity Index	Plasticity
0	Non plastic
1 - 5	Slight
5 - 10	Low
10 - 20	Medium
20 - 40	High
> 40	Very high

∴ Soil is of low plasticity.

112. (a)

Entrapped air and organic impurities, these factors obstruct the flow in the soil voids, and hence reduce the permeability. therefore, complete saturation of a sample should be done before performing a permeability test.

$$K \propto \frac{1}{\text{Foreign umpurity}} \text{ or } \frac{1}{\text{Organic impurity}}$$

$$K \propto \frac{1}{\text{Entrapped air}} \propto \text{Saturation(s)}$$

$$K \propto \frac{1}{\text{Viscosity}}$$

113. (d)

Given: $\gamma_b = 19.62 \text{ kN/m}^3, S = 0.5, \gamma_w = 9.81 \text{ kN/m}^3$

$$\gamma_b = \frac{(G+Se)\gamma_w}{1+e}$$

$$\Rightarrow \quad 19.62\,(1+e) = (2.75 + 0.5e)\, 9.81$$

$$e = 0.5$$

$$\therefore \quad i = \frac{G-1}{1+e} = \frac{1.75}{1.5} = 1.16$$

114. (a)

115. (a)

Given: For test sample,

$$\%u = 90\%,\ H = 20 \text{ mm}, \qquad \left\{d = \frac{H}{2} \therefore \text{Double Drainage}\right\}$$

$$t = 2 \text{ hours}$$

For field, $\%u = 90\%$ and $H = 4$ m, $d = 2$ m

$$\because \quad T_v = \frac{C_v T}{d^2}$$

$$\Rightarrow \quad \frac{T_v}{C_v} = \frac{t}{d^2}, \qquad \therefore \quad \frac{2}{\left(\frac{0.02}{2}\right)^2} = \frac{t}{\left(\frac{4}{2}\right)^2}$$

$$\Rightarrow \quad t = 8 \times 10^4 \text{ hr}$$

$$\Rightarrow \quad t = \frac{8 \times 10^4}{24 \times 365} = 9.132 \text{ years} \simeq 9.1 \text{ years}$$

116. (d)

$$\text{FOS} = \frac{C + \gamma_{sub} Z \cos^2\beta \tan\phi}{\gamma_{sub} Z \cos\beta \sin\beta}$$

For critical, height, $\text{FOS} = 1$ and $Z = H_C$

$$\therefore \quad \gamma_{sub} H_C \cos\beta\sin\beta = C + \gamma_{sub} H_C \cos^2\beta\tan\phi$$

$$\Rightarrow \quad C = \left(\gamma_{sub} H_C \cos^2\beta(\tan\beta - \tan\phi)\right)$$

$$\Rightarrow \quad H_C = \frac{C}{\gamma_{sub}\cos^2\beta(\tan\beta - \tan\phi)}$$

117. (a)

Given: $\phi = 30°, C = 3.0 \text{ kg/cm}^2, \sigma_1 = 18 \text{ kg/cm}^2$

$$\theta_c = 45° + \frac{\phi}{2} = 45° + \frac{30°}{2} = 60°$$

$$\therefore \quad \sigma_1 = \sigma_3 \tan^2\theta_c + 2C\tan\theta_c$$

$$\Rightarrow \quad 18 = \sigma_3 \tan^2 60° + 2 \times 3 \tan 60°$$

$$\Rightarrow \quad 18 = 3\sigma_3 + 6\sqrt{3}$$

$$\Rightarrow \quad \sigma_3 = \frac{18 - 10.39}{3}$$

$$\Rightarrow \quad \sigma_3 = 2.54 \text{ kg/cm}^2$$

118. (a)

Since the wall is restrained from yielding, the wall will be subjected to earth pressure at rest, which given by

$$P_o = \frac{1}{2} k_o \gamma H^2$$

$$K_o = 1 - \sin\phi = 1 - \sin 30° = 0.5$$

$$\therefore \quad P_o = \frac{1}{2} \times 0.5 \times 19 \times 6^2 = 171 \text{ kN/m length of wall}$$

119. (a)

Given, $q_u = 80 \text{ kN/m}^2, C_u = \frac{q_u}{2} = 40 \text{ kN/m}^2$

Using Skempton's equation, $q_{nf} = 5\left[1 + 0.2\frac{B}{L}\right]\left[1 + 0.2\frac{D_F}{B}\right]$

$$\Rightarrow \quad q_{nf} = 5\left[1 + 0.2 \times \frac{10}{20}\right]\left[1 + 0.2\frac{D}{20}\right]$$

$$\Rightarrow \quad q_{nf} = 5.5\,[1 + 0.01\,D]$$

Given; $q_s = 120 \text{ kN/m}^2$,

$$q_s = \frac{q_{nf}}{FOS} + \gamma D_f = \frac{5.5}{2.2} + \frac{5.5 \times 0.01}{2.2} D + 15D$$

$$\Rightarrow \quad 120 = 2.5 + 15.025\,D$$

$$\Rightarrow \quad D = 7.82 \text{ m} \simeq 7.8 \text{ m}$$

120. (d)

The ratio of the ultimate load capacity of the pile group, Q_{ug} to the sum of the individual load capacities of the piles in the group, is called group efficiency η.

$$\eta = \frac{Q_{ug}}{nQ_u}$$

Disturbance of soil during installation of piles and overlap of stresses between adjacent piles may cause the group capacity to become less than the sum of the individual capacities, i.e. $\eta < 1$. Generally, for smaller spacing between piles, $\eta < 1$. For larger spacing, the effect of pile interaction diminishes and η approaches unity. In driven piles where the soil around the piles gets densified, as in loose to medium sand, η may be even more than 1.

As per IS-2911, Part IV the allowable load on single pile will be minimum of the following two cases:

1. $\frac{2}{3}$ rd of the load at which total settlement is 12 mm.

2. 50% of the ultimate load at which total settlement is equal to the $\left(\frac{1}{10}\right)^{th}$ of the diameter of pile.
3. $\frac{1}{2}$ to $\frac{2}{3}$ rd of the load which gives a net settlement of 6 mm.

121. (b)

Optimum number of rain gauges, $N = \left(\frac{C_v}{\epsilon}\right)^2$

$$C_v = \text{Coefficient of variance} = 100\frac{\sigma}{\overline{p}}$$

$$\overline{p} = \text{Mean rainfall} = \frac{800+600+700+900}{4}$$

$$= 750 \text{ mm}$$

$$C_v = 100\times\frac{130}{750} = 17.33\%$$

$$\therefore \quad N = \left(\frac{17.33}{10}\right)^2 = 3.003 \simeq 3 \text{ (say)}$$

Optimum number of raingauge is 3

122. (b)

Ranking of storm, $m = \frac{N}{T}$

N = Total numbers of years on record = 10

T = Recurrence interval = 5 years

$$m = \frac{10}{5} = 2$$

Therefore, we have to choose 2nd severest storm. i.e. 71.2 cm

123. (b)

Infiltration rate f_t after 't' hr is

$$f_t = K\left[\frac{\Psi\Delta w}{F_t}+1\right] = 0.12\left[\frac{9\times0.3}{2}+1\right]$$

$$\Rightarrow \quad f_t = 0.282 \text{ cm/hr}$$

124. (c)

As per U.S. Army Corps of Engineers empirical relations, width of hydrograph at discharge equal to 50% and 75% of peak discharge,

$$w_{50} = \frac{5.87}{q_p^{1.08}} = \frac{5.87}{(1.08)^{1.08}} = 5.39 \text{ hr}$$

$$w_{75} = \frac{w_{50}}{1.75} = \frac{5.39}{1.75} = 3.08 \text{ hr}$$

125. (d)

- Ephemeral streams flow only in direct response to precipitation.
- They lack well-developed channel morphology due to intermittent flow.
- Sequent peak algorithm is used in reservoir storage analysis.

126. (c)

A station rating curve is essentially a stage-discharge relationship established for a specific gauging station.

127. (c)

Stream density (stream frequency) is defined as the number of streams per unit area, not the total length. The total length of streams per unit area defines drainage density, not stream frequency.

128. (c)

Discharge over the spillway in uncontrolled ogee spillway is,

$$Q = C_d L H^{3/2}$$
$$= 2.1 \times 40 \times 4^{3/2} = 672 \text{ m}^3/\text{s}$$

129. (c)

Total horizontal wave pressure per meter length of the dam,

$$P_w = 2.0\,\gamma_w h_w^2$$
$$= 2.0 \times 10 \times 2^2 = 80 \text{ kN/m}$$

Location of resultant wave pressure $= \dfrac{3h_w}{8}$ above still water level

$$= 3 \times \frac{2}{8} = 0.75 \text{ m}$$

130. (c)

Net irrigation requirement, NIR $= C_u - R_e$

$= 124 - 44 = 80$ cm

Field irrigation requirement, FIR $= \dfrac{NIR}{\eta_a} = \dfrac{80}{0.50}$

$= 160$ cm

Gross irrigation requirement, GIR $= \dfrac{FIR}{\eta_c} = \dfrac{160}{0.80}$

$= 200$ cm

131. (d)

Principal stress at the toe,

$$\sigma = p_v \sec^2\alpha - (p' - p'_e)\tan^2\alpha$$

where p_v = Vertical normal stress = 120 kN/m^2

p' = Water pressure intensity = 60 kN/m^2

p'_e = Hydrodynamic pressure = 20 kN/m^2

$$\sigma = 120 \sec^2 45° - (60 - 20)\tan^2 45°$$

$$= 200 \text{ kN/m}^2$$

Shear stress on horizontal plane near toe,

$$\tau = (p_v - (p' - p'_e) \tan \alpha$$
$$= (120 - (60 - 20)) \tan 45°$$
$$= 80 \text{ kN/m}^2$$

132. (a)

- Mutual pile interference causes redistribution of pressures; sign depends on whether the point is in rear (positive) or forward (negative) zone.
- Thickness correction is essential because pressures are computed at the top of floor but act at the bottom.
- Correction for slope is positive for downward slopes and negative for upward slopes, not upstream/downstream.

133. (d)

Setting of an weir type outlet is 0.9

134. (a)

- Useful storage lies between minimum pool level (MPL) and normal pool level (NPL).
  This is the actively usable storage for irrigation, water supply and power.
- Surcharge storage exists only during floods.
  It lies between normal pool level and maximum pool level.
  It is uncontrolled and temporary.
- Bank storage is water that seeps into reservoir banks and later returns.
  It is temporary and depends on permeability and geology.
  It does not remain permanently stored.
- Effective storage is not defined as useful storage reduced by bank storage.
  Effective storage for flood mitigation = Useful storage + Surcharge storage – Valley storage

135. (b)

For a hydraulic jump

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1+\sqrt{1+8F_1^2}\right)$$

$$\Rightarrow \quad \frac{0.8}{0.5} = \frac{1}{2}\left(-1+\sqrt{1+8F_1^2}\right)$$

$$\Rightarrow \quad 3.2 = \left(-1+\sqrt{1+8F_1^2}\right)$$

$$\Rightarrow \quad F_1^2 = 2.08$$

For rectangular channel, $F^2 = \dfrac{Q^2T}{gA^3} = \dfrac{v^2}{gy}$

$$\Rightarrow \quad 2.08 \times 10 \times (1 \times 0.5)^3 = Q^2 \times 1$$

$$\Rightarrow \quad Q = 1.61 \text{ m}^3/\text{s}$$

136. (b)

In RVF frictional losses are usually negligible.

In GVF, curvature is small and pressure is hydrostatic.

137. (d)

Let y_1 and y_2 be the alternate depth

$$\text{Specific energy, } E = y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g}$$

$$y_1\left(1+\frac{v_1^2}{2gy_1}\right) = y_2\left(1+\frac{v_2^2}{2gy_2}\right)$$

$$\frac{y_1}{y_2} = \frac{\left(1+F_2^2/2\right)}{\left(1+F_1^2/2\right)} \qquad \left(\because\ F = \frac{v}{\sqrt{gy}}\right)$$

$$\frac{y_1}{y_2} = \frac{2+F_2^2}{2+F_1^2} \qquad \ldots\text{(i)}$$

Now,

$$F_1^2 = \frac{v_1^2}{gy_1} = \frac{Q^2}{B^2gy_1^3} \text{ and } F_2^2 = \frac{Q^2}{B^2gy_2^3}$$

$$\frac{y_1^3}{y_2^3} = \left(\frac{F_2}{F_1}\right)^2 \Rightarrow \frac{y_1}{y_2} = \left(\frac{F_2}{F_1}\right)^{2/3} \qquad \ldots\text{(ii)}$$

From equations (i) and (ii)

$$\frac{y_1}{y_2} = \left(\frac{F_2}{F_1}\right)^{2/3} = \left(\frac{2+F_2^2}{2+F_1^2}\right)$$

138. (c)

$$\text{Load factor} = \frac{\text{Average load during a certain period}}{\text{Peak load during that period}}$$

$$= \frac{9000000\,kWh}{10^5 \times 7 \times 24\ kWh} = 0.535$$

$$= 53.5\%$$

139. (b)

Fire-shielding mortars are used for setting refractory bricks in the furnace linings where the temperature is too high for ordinary mortars.

Aluminous cements and finely powdered fire bricks in the ratio 1 : 2 give excellent fire resisting mortars. Its trade name is Accoset 50.

Sound-absorbing mortars : These are prepared by mixing water with binding materials such as cement, slag cement, lime, or gypsum, and lightweight porous fine aggregates made from pumice, cinders, and ceramsite. They have a bulk density of 6-12 kN/m^3.

140. (b)

- Definition of true regime: No silting/scouring due to sediment-flow equilibrium.
- Bank rigidity can provide stability, but this is NOT the reason for true regime.
- True regime stability is due to alluvial adjustment, not bank rigidity (which is relevant to initial regime).

141. (a)

Lime causes flocculation and agglomeration of clay particles, which reduces liquid limit and increases plastic limit, thereby decreasing the plasticity index.

142. (a)

Mosaics generally have an overall average scale, not a uniform scale everywhere.
Variations in flying height and presence of tilt/relief cause scale variation.
Statement (I) correctly explains Statement (II).

143. (a)

In summer mid-day, temperature gradient causes downward warping, inducing tensile stress at the bottom. Load stress at the edge is higher than at the interior. Warping stress and load stress are additive at the edge. Frictional stress due to expansion is compressive and small, hence reduces tensile stress only marginally. Therefore, the edge becomes critical.

144. (b)

The fundamental cause of zero DO is the extremely high organic load and anaerobic decomposition, not merely the imbalance of rates.

145. (a)

For hydraulically smooth pipes, friction factor depends only on Reynolds number
Roughness lies inside viscous (laminar) sublayer, so it does not affect turbulence.

146. (c)

Statement I is true but Statement II is false.
IRC suggests that the FI of aggregates used in water bound macadam and bituminous macadam should not exceed 15%.

147. (a)

Dumpers are suitable for both short and long haul as per requirement of work. Also they have advantage of high capacity.

148. (a)

To limit the width of shear crack, strain in shear reinforcement should be limited.

149. (b)

150. (b)

In simple bending, strain in the bent beam varies linearly across the beam depth.
This happens because of the fundamental bending assumption:
"Plane sections before bending remain plane after bending."