DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 12

Section A : Design of Concrete and Masonry Structures [All Topics]

Section B : Structural Analysis-I [Part Syllabus]

Section C : CPM PERT-II + Hydrology and Water Resource Engg-II [Part Syllabus]

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

DETAILED EXPLANATIONS

1. (a)

For the given loading, the tensile stress in the bar segment varies from maximum at continuous end D to practically zero at the discontinuous end C. Therefore the probable variation of anchorage bond stress will be maximum at D and zero at C.

2. (b)

Given,
$$b = 350 \text{ mm}$$
$$D = 700 \text{ mm}$$
$$M_u = 200 \text{ kN–m}$$
$$T_u = 140 \text{ kN–m}$$

Effective bending moment due to torsion

$$M_T = \frac{T_u}{1.7}\left[1+\frac{D}{b}\right]$$
$$= \frac{140}{1.7}\left[1+\frac{700}{350}\right]$$
$$= \frac{140\times 3}{1.7} = 247.05 \text{ kN} - \text{m}$$

∴ Equivalent bending moment for design of flexural tension at bottom

$$M_C = M_T - M_u$$
$$= 247.05 - 200 = 47.05 \text{ kN–m}$$

3. (a)

The code specifies minimum and maximum limits for the spacing between parallel reinforceing bars in a lyer. The minimum limits are necessary to ensure that the concrete can be placed easily in between and around the bars during the placement of fresh concrete. The maximum limits are specified for bars in tension for the purpose of controlling crack-widths and improving bond.

4. (a)

Given,
$$\tau_C = 0.29 \text{ N/mm}^2$$
$$V = 100 \text{ kN}$$
$$b = 250 \text{ mm}$$
$$d = 400 \text{ mm}$$

The shear reinforcement is provided to carry a shear force, V_s

$$V_s = V - \tau_C \text{ (bd)}$$
$$= 100 - 0.29\ (250 \times 400) \times 10^{-3}$$
$$= (100 - 29) \text{ kN} = 71 \text{ kN}$$

5. (a)

Exposure condition	Minimum concrete grade	Nominal cover (mm)
Mild	M20	20
Moderate	M25	30
Severe	M30	45
Very severe	M35	50
Extreme	M40	75

6. (b)

Modulus of rupture for M 20 concrete,

$$f_{cr} = 0.7\sqrt{f_{ck}}$$
$$= 0.7 \times \sqrt{20}$$
$$= 3.13 \text{ N/mm}^2$$

$$\text{Section modulus, } Z = \frac{bD^2}{6}$$
$$= \frac{400 \times 600^2}{6}$$
$$= 24 \times 10^6 \text{ mm}^3$$

∴ Cracking moment,

$$M_{cr} = f_{cr} \cdot Z$$
$$= 3.13 \times 24 \times 10^6$$
$$= 75.12 \times 10^6 \text{ N – mm}$$
$$= 75.12 \text{ kN-m}$$

7. (b)

Refer IS 456 : 2000.

9. (d)

Effective width of flange,

$$b_f = \frac{0.5\,L_0}{\frac{L_0}{b} + 4} + b_w$$
$$= \frac{0.5 \times 10000}{\frac{10000}{800} + 4} + 200$$
$$= \frac{5000}{16.5} + 200$$
$$= 503.03 \text{ mm} < 800 \text{ mm} (= b)$$
$$\simeq 503 \text{ mm}$$

11. (d)

Refer IS 456 : 2000, Clause 17.6

13. (b)

$$\text{Spacing between vertical stirrups} \ngtr \text{Minimum}\begin{cases}0.75\,d = 0.75 \times 300 = 225\,\text{m}\\ 300\text{ mm}\end{cases}$$

So, maximum spacing $\ngtr$ 225 mm

14. (b)

As per IS 456 : 2000.

Minimum area of reinforcement required,

$$\frac{A_{st}}{Bd} \geq \frac{0.85}{f_y}$$

$$\Rightarrow \quad A_{st} \geq \frac{0.85 \times 250 \times 500}{250}$$

$$\Rightarrow \quad A_{st} \geq 425\text{ mm}^2$$

$\therefore$ Minimum area of steel required is 425 mm^2.

15. (c)

Refer IS 456 : 2000, Clause 32.5.

16. (b)

The bars shall not be less than 12 mm in diameter.

Refer IS 456 : 2000, Clause 26.5.3.1

17. (b)

As per IS 456 : 2000, Clause 23.2.1,

For simply supported beam,

$$\text{Depth} \nless \frac{\text{Span}}{20 \times MF_T \times MF_C \times \left(\dfrac{10}{\text{Span}}\right)}$$

where MF_T and MF_C are modification factors due to tension and compression respectively.

$$\therefore \quad \text{Depth} \nless \frac{15}{20 \times 0.9 \times 1.1 \times \dfrac{10}{15}}$$

$$\Rightarrow \quad d \nless \frac{15}{13.2}$$

$$\Rightarrow \quad d \nless 1.14$$

18. (b)

Since the column is rigidly fixed at both the ends,

$$\therefore \quad L_{eff} = 0.65\,L_0$$

$$\Rightarrow \quad 4.55 = 0.65\,L_0$$

$$\Rightarrow \quad L_0 = 7\text{ m}$$ [where L_0 is unsupported length]

As per IS : 456, Clause 39.2

$$e_{min} \text{ (minimum eccentricity)} = \text{Max. of} \begin{cases} \dfrac{\text{Unsupported length of column}}{500} + \dfrac{\text{Lateral dimension}}{30} \\ or \\ 20 \text{ mm} \end{cases}$$

$$= \text{Max. of} \begin{cases} \dfrac{7000}{500} + \dfrac{500}{30} \simeq 30.67 \text{ mm} \\ or \\ 20 \text{ mm} \end{cases}$$

$$\therefore \quad e_{\min} = 30.67 \text{ mm}$$

19. (b)

$$\text{Working axial load} = \frac{\text{Factored axial load}}{1.5}$$

$$= \frac{2400}{1.5}$$

$$= 1600 \text{ kN}$$

$$\therefore \quad \text{Allowable bearing pressure} = \frac{1600 \times 10^3}{500 \times 400} \text{ N/mm}^2$$

$$= 8 \text{ N/mm}^2$$

20. (a)

As per IS : 456, Clause 26.5.3.2, spacing of lateral ties

$$S_V \leq \begin{cases} \text{Least lateral dimension} \\ 16\phi_{\text{long.min}} \\ 300 \text{ mm} \end{cases}$$

$$\Rightarrow \quad S_V = \text{min. of} \begin{cases} 400 \text{ mm} \\ 16 \times 16 = 256 \text{ mm} \\ 300 \text{ mm} \end{cases} = 256 \text{ mm}$$

$$\therefore \quad \text{Provide } S_V = 256 \text{ mm}$$

22. (a)

For main reinforcing bars

$$\text{Maximum spacing} = \text{min. of} \begin{cases} 3d = 3(80) = 240 \text{ mm} \\ or \\ 300 \text{ mm} \end{cases}$$

$$= 240 \text{ mm}$$

For distribution bars,

$$\text{Maximum spacing} = \text{min. of} \begin{cases} 5d = 5 \times 80 = 400 \text{ mm} \\ or \\ 450 \text{ mm} \end{cases}$$

$$= 400 \text{ mm}$$

23. (c)

For one way shear,

Net pressure on the footing,

$$w = \frac{420}{2 \times 2} \text{kN/m}^2$$

$$= 105 \text{ kN/m}^2$$

The critical section for one way shear is at a distance 'd' from the face of the column.

$$V = wB \times \left[\frac{1}{2}(B - b) - d\right]$$

$$= 105 \times 2 \times \left[\frac{1}{2}(2 - 0.3) - 0.25\right]$$

$$= 126 \text{ kN}$$

24. (a)

As per IS 3370 (Part-2): 2009, Clause 8.1, the minimum reinforcement within each surface zone shall not be less than 0.24% of the surface zone.

25. (a)

Maximum compressive stress in concrete,

$$\sigma = \frac{P}{A} + \frac{Pe}{Z}$$

$$= \frac{400 \times 10^3}{250 \times 400} + \frac{400 \times 10^3 \times 100 \times 6}{250 \times 400^2}$$

$$= 4 + 6$$

$$= 10 \text{ N/mm}^2$$

26. (c)

Loss of stress due to creep of concrete

$$= \phi \cdot m \cdot f_c$$

$$= 1.5 \times 7 \times 7$$

$$= 73.5 \text{ N/mm}^2$$

27. (c)

Under reinforced section performs better on ductility criterion as the reinforcement yields prior to failure giving sufficient warning by ensuring cracking in concrete before it fails in flexure.

29. (a)

The uniformly distributed load exerted by parabolic profile is given by

$$w = \frac{8Pe}{l^2}$$

For external load of 20 kN/m exactly balancing, the upward load,

$$20 = \frac{8 \times 1500 \times e}{8^2}$$

$$\Rightarrow \quad e = \frac{20 \times 8}{1500} \times 1000 \text{ mm}$$

$$= 106.67 \text{ mm}$$

Equation of parabolic profile is given by,

$$y = \frac{4\,ex}{l^2}(l - x)$$

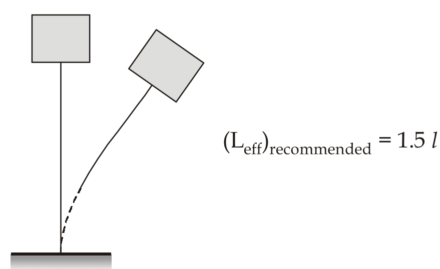
$$= \frac{4 \times 106.67 \times 10^{-3} \times x \times (8 - x)}{8^2}$$

$$= 6.67x\,(8 - x) \times 10^{-3}$$

$$= 6.67 \times 10^{-3} \times (8x - x^2)$$

30. (c)

Refer table 28 of IS 456 : 2000.



31. (b)

Refer IS 456 : 2000, Clause 26.2.3

32. (a)

As per *Cl*. 7.6.2 (c) of IS : 1893-2016,

$$T = \frac{0.09h}{\sqrt{d}}$$

where h = Height of building

d = Plan dimension

In longer direction, d = 25 m

$$\therefore \quad T = \frac{0.09 \times 80}{\sqrt{25}} = \frac{0.09 \times 80}{5}$$

$$= 1.44 \text{ sec}$$

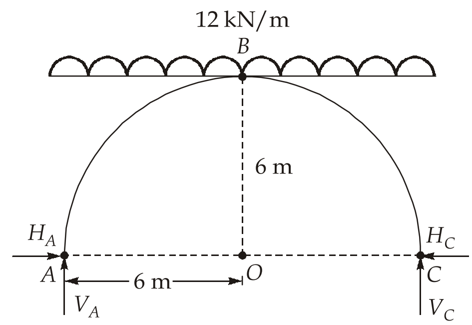
35. (c)

In reinforced concrete sections, the load carrying mechanism is the constant lever arm with changing force.

36. (d)

As per IS 456 : 2000, development length of each bar of bundled bars shall be that for the individual bar, increased by 10 percent for two bars in contact, 20 percent for three bars in contact and 33 percent for four bars in contact.

37. (d)



$$V_A = V_C = \frac{12\times 12}{2} = 72 \text{ kN } [\because \text{ Due to symmetry}]$$

Now, $M_B = 0$ [from right]

$$\Rightarrow \quad 12 \times 6 \times 3 - V_C \times 6 + H_C \times 6 = 0$$

$$\Rightarrow \quad 36 - 72 + H_C = 0$$

$$\Rightarrow \quad H_C = 36 \text{ kN}$$

38. (b)

Material should be elastic and should follow Hooke's law.

39. (a)

For vertical loading

Number of external reactions, $r_e = 5$ (V_A, M_A, V_B, V_C, and V_D)

Number of reactions released, $r_r = 1$ (hinge at E)

Number of equations available = 2

So, degree of static indeterminacy,

$$D_s = r_e - 2 - r_r = 5 - 2 - 1 = 2$$

40. (c)

Increase in rise of arch,

$$\Delta h = \frac{l^2 + 4h^2}{4h} \times \alpha \times \Delta T$$

$$= \left(\frac{25^2 + 4\times 5^2}{4\times 5}\right) \times 12\times 10^{-6} \times 40$$

$$= 0.0174 \text{ m} = 17.4 \text{ mm}$$

41. (c)

Stiffness matrix method is an example of displacement method of analysis.

42. (a)

For simply supported beam, subjected to point load at mid-span,

Maximum bending moment, $M_{max} = \dfrac{PL}{4} = \dfrac{25\times 8}{4} = 50$ kN–m

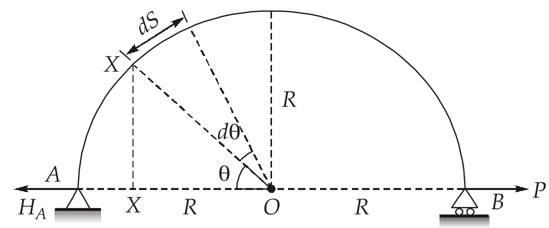
For fixed beam subjected to point load at mid-span,

Maximum bending moment, $M_{max} = \frac{WL}{8}$

Now, $\frac{WL}{8} = 50$

$\Rightarrow \quad W = \frac{50 \times 8}{8} = 50 \text{ kN}$

43. (d)



Take an element at an angle θ as shown in figure.

$\Sigma F_x = 0$

$\Rightarrow \quad H_A - P = 0$

$\Rightarrow \quad H_A = P$

$V_A = V_B = 0$

Now, moment at section, X - X

$M_x = H_A R \sin\theta$

$= PR \sin\theta$

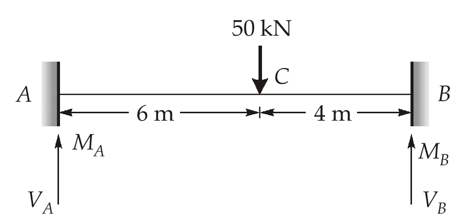
Strain energy, $U = \int \frac{M_x^2 dS}{2EI} = \int_0^{\pi} \frac{(PR\sin\theta)^2 Rd\theta}{2\,EI}$

$= \frac{P^2R^3}{2\,EI}\int_0^{\pi} \sin^2\theta\, d\theta$

$= \frac{P^2R^3}{2\,EI} \times \frac{\pi}{2} = \frac{P^2R^3\pi}{4\,EI}$

Now, Deflection at B, $\Delta_{HB} = \frac{\partial U}{\partial P} = \frac{PR^3\pi}{2\,EI}$

44. (c)



$M_{AB} = \frac{-50 \times 6 \times 4^2}{10^2}$

$= -48 \text{ kN - m}$

$M_{BA} = \frac{50 \times 6^2 \times 4}{10^2}$

$= 72 \text{ kN - m}$

Now, $\Sigma M_B = 0$

$\Rightarrow \quad V_A \times 10 - 48 - 50 \times 4 + 72 = 0$

$\Rightarrow \quad V_A = 17.6 \text{ kN}$

45. (b)

Minimum tension in cable, T_{min} = Horizontal reaction

$= \frac{wl^2}{8\,h}$

$$= \frac{10\times 100^2}{8\times 8} = 1562.5 \text{ kN}$$

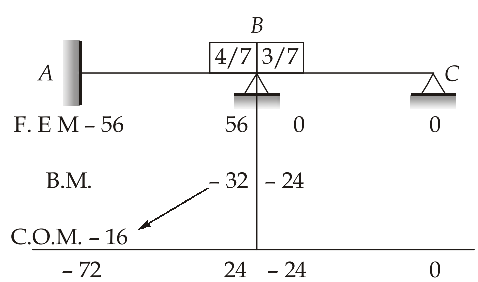
46. (b)

$$M_{FAB} = -\frac{WL}{8} = \frac{-112\times 4}{8} = -56 \text{ kN}-\text{m}$$

$$M_{FBA} = \frac{WL}{8} = \frac{112\times 4}{8} = 56 \text{ kN}-\text{m}$$

Joint	Member	Stiffness	Total Stiffness	Distribution factor
	BA	$\frac{4\ EI}{4}$		$\frac{4}{7}$
B			$\frac{7\ EI}{4}$	
	BC	$\frac{3\ EI}{4}$		$\frac{3}{7}$

Moment distribution is done below.



47. (d)

Bending moment is zero every where in cable subjected to uniformly distributed load.

- Tension is minimum at mid-span.

48. (b)

Degree of kinematic indeterminacy,

$$D_k = 3j - r_e = 3 \times 10 - 6 = 24$$

49. (c)

$$M_{FBC} = M_{FCB} = \frac{M_0}{4} = \frac{40}{4} = 10 \text{ kN} - \text{m}$$

Using slope-deflection equations

$$M_{BC} = M_{FBC} + \frac{2\,EI}{6}(2\theta_B + \theta_C)$$

$$= 10 + \frac{2}{3}EI\theta_B \qquad [\because \theta_C = 0]$$

$$M_{BA} = M_{FBA} + \frac{2\,EI}{6}(2\theta_B + \theta_A)$$

$$= \frac{2}{3}EI\theta_B \qquad [\because \quad \theta_A = 0]$$

Now, $$M_{BC} + M_{BA} = 0$$

$$\Rightarrow \quad 10 + \frac{2}{3}EI\theta_B + \frac{2}{3}EI\theta_B = 0$$

$$\Rightarrow \quad \theta_B = \frac{-15}{2\,EI}$$

50. (c)

In a linear arch, shape of static bending moment i.e. the bending moment in the corresponding simply supported beam due to applied loads is same as shape of arch axis.

51. (a)

The general expression for annual depreciation for any year (m) when the life is n years is expressed as:

$$D_m = (C_i - C_S)\left[\frac{n-m+1}{\frac{n(n+1)}{2}}\right]$$

Now, depreciation at the end of 2nd year is given by

$$D_2 = (1000-200)\left[\frac{5-2+1}{\frac{5(5+1)}{2}}\right]$$

$$= ₹213.33$$

54. (b)

In item rate contract, the changes in drawing and quantities of individual item can be made as per requirements within agreed limits.

56. (d)

Overhead charges may be devided under two catagories viz.:

(A) General overhead

(B) Job overhead

(A) All the expenses related to the contractor's office and establishment are termed as general overhead.

(B) The expenses directly related to execute a job or project are termed as job overhead.

58. (c)

Letter of intent is not a legal document.

59. (a)

Capital recovery factor is given by,

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$\Rightarrow \quad CRF = \frac{(0.08)(1+0.08)^2}{(1+0.08)^2 - 1}$$

$$= 0.56$$

61. (a)

Discharge required at the head of canal considering 25% losses $= \frac{6.25}{0.75}$

$$= \frac{25}{3}$$

$$\therefore \quad \text{Duty on capacity} = \frac{\text{Area to be irrigated}}{\text{Discharge required at the head of canal}}$$

$$= \frac{5200}{\frac{25}{3}} = \frac{5200 \times 3}{25}$$

$$= 624 \text{ ha/cumecs}$$

63. (d)

- The yield of a crop increases upto a certain limit and then decreases with increase in water content.
- The duty of irrigation water for a given crop is maximum on the field.

65. (c)

Water logging is not caused by salinity.

67. (c)

Meander belt or meander width

$$M_B = 150\sqrt{Q} \qquad \text{[where } Q \text{ is in m}^3\text{/s]}$$

$$= 150\sqrt{1225}$$

$$= 150 \times 35$$

$$= 5250 \text{ m}$$

$$= 5.25 \text{ km}$$

68. (b)

At ultimate wilting point, available water content is 0. Hence $AET = 0$

At field capacity, AET = PET

69. (a)

Here, water depth required at canal outlet

$$= \frac{\text{Water depth required in field}}{\eta_a \times \eta_c}$$

$$= \frac{10}{0.8 \times 0.9} \qquad \begin{bmatrix} \because \text{ Conveyance losses } = 10\% \\ \therefore \qquad n_c = 90\% \end{bmatrix}$$

$$= 13.89 \text{ cm}$$

∴ Volume of water required for 5 ha field

$$= 5 \times 10^4 \times 13.9 \times 10^{-2} \text{ m}^3$$

$$= 6945 \text{ m}^3$$

70. (b)

For a triangular lined canal with rounded corners,

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

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

∴ Hydraulic radius, $R = \frac{A}{P}$

$$= \frac{y^2(\theta + \cot\theta)}{2y(\theta + \cot\theta)}$$

$$= \frac{y}{2}$$

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

71. (d)

Due to development of tension cracks, crack-area looses contact with the bottom of foundation. Hence base width will be reduced and p_{max} increases. Also, this results in increase in uplift, therefore net effective downward force reduces.

72. (c)

Sodium absorption ratio,

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

where concentrations are in meq/l.

∴ $[Na^+] = \frac{368}{\text{Equivalent weight of Na}}$

$$= \frac{368}{23} = 16 \text{ meq/l}$$

$$\therefore \quad [Ca^{+2}] = \frac{60}{\text{Equivalent weight of Ca}}$$

$$= \frac{60}{20} = 3 \text{ meq/l}$$

$$\therefore \quad [Mg^{+2}] = \frac{18}{\text{Equivalent weight of Mg}}$$

$$= \frac{18}{12} = 1.5 \text{ meq/l}$$

$$\therefore \quad SAR = \frac{16}{\sqrt{\frac{3+1.5}{2}}} = \frac{16}{1.5} \simeq 10.67$$

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