DETAILED SOLUTIONS

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ESE 2026 : 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.	(c)	16.	(c)	31.	(d)	46.	(a)	61.	(a)
2.	(b)	17.	(c)	32.	(d)	47.	(d)	62.	(d)
3.	(b)	18.	(c)	33.	(d)	48.	(a)	63.	(d)
4.	(b)	19.	(b)	34.	(a)	49.	(a)	64.	(a)
5.	(a)	20.	(b)	35.	(d)	50.	(d)	65.	(d)
6.	(c)	21.	(b)	36.	(b)	51.	(b)	66.	(b)
7.	(c)	22.	(d)	37.	(c)	52.	(b)	67.	(b)
8.	(d)	23.	(d)	38.	(b)	53.	(a)	68.	(d)
9.	(c)	24.	(b)	39.	(b)	54.	(a)	69.	(d)
10.	(c)	25.	(d)	40.	(c)	55.	(d)	70.	(c)
11.	(d)	26.	(c)	41.	(a)	56.	(c)	71.	(a)
12.	(b)	27.	(a)	42.	(d)	57.	(d)	72.	(a)
13.	(a)	28.	(a)	43.	(d)	58.	(a)	73.	(a)
14.	(a)	29.	(a)	44.	(b)	59.	(d)	74.	(d)
15.	(d)	30.	(b)	45.	(b)	60.	(d)	75.	(a)

DETAILED EXPLANATIONS

Section A : Design of Concrete and Masonry Structures

1. **(c)**

Effective depth, d, is the distance between the extreme compression fibre and the centroid of the area of tension reinforcement. When measuring d, exclude any finishing material not placed monolithically with the member and any concrete thickness provided only to allow for wear.

2. **(b)**

As per Clause 6.2.2 of IS 456:2000, modulus of rupture of concrete, f_{cr} is given as

$$f_{cr} = 0.7\sqrt{f_{ck}} = 0.7\sqrt{30}$$

$$\Rightarrow \quad f_{cr} = 3.83 \text{ MPa}$$

3. **(b)**

Cracking moment, $$M_{cr} = \frac{f_{cr} I_g}{y_t} = f_{cr} Z$$

where $$f_{cr} = 0.7\sqrt{f_{ck}} = 0.7 \times \sqrt{25} = 3.5 \text{ MPa}$$

$$Z = \frac{bD^2}{6}$$

$$\Rightarrow \quad Z = \frac{300 \times 500^2}{6} = 12.5 \times 10^6 \text{ mm}^3$$

Now, $$M_{cr} = 3.5 \text{ MPa} \times 12.5 \times 10^6 \text{ mm}^3$$

$$\Rightarrow \quad M_{cr} = 43.75 \times 10^6 \text{ N-mm}$$

$$\Rightarrow \quad M_{cr} = 43.75 \text{ kN-m}$$

4. **(b)**

Longitudinal reinforcement requirements in columns:

- The minimum number of longitudinal bars required in a column is four in rectangular sections and six in circular sections.
- The diameter of longitudinal bars shall not be less than 12 mm.
- A column with helical reinforcement shall have at least six longitudinal bars placed within the helical reinforcement.
- In helically reinforced columns, the longitudinal bars shall remain in contact with the helix and be arranged equidistant around the inner circumference.
- The spacing of longitudinal bars measured along the periphery of a column shall not exceed 300 mm.
- In pedestals where longitudinal reinforcement is not considered in strength calculations, nominal reinforcement of at least 0.15% of the cross-sectional area shall be provided.

5. (a)

Stress in concrete at level of steel,

$$\sigma_c = \frac{P}{A} = \frac{300 \times 1000}{200 \times 400} = 3.75 \text{ N/mm}^2$$

Loss of prestress due to creep of concrete is given by.

$$\Delta\sigma = \theta \times m \times \sigma_c \qquad \left\{\text{where, } m = \frac{E_s}{E_c}\right\}$$

$$\Rightarrow \quad \Delta\sigma = 2 \times 8 \times 3.75 \text{ N/mm}^2$$

$$\Rightarrow \quad \Delta\sigma = 60 \text{ N/mm}^2$$

6. (c)

According to Clause 25.4 of IS 456 : 2000, all columns shall be designed for a minimum eccentricity equal to the unsupported length of column/500 plus lateral dimensions/30, subject to a minimum of 20 mm.

Hence,

$$e_{\min} = \frac{L}{500} + \frac{D}{30}$$

$$\Rightarrow \quad e_{\min} = \frac{3000}{500} + \frac{450}{30} = 21 \text{ mm} > 20 \text{ mm}$$

$$\Rightarrow \quad e_{\min} = 21 \text{ mm}$$

7. (c)

Assumptions for Limit State of Collapse in flexure:

- Plane sections normal to the axis are assumed to remain plane after bending, forming the basis of strain compatibility in flexural design.
- The maximum strain in concrete at the outermost compression fibre is limited to 0.0035 in bending.
- The compressive stress-strain curve of concrete may be taken as rectangular, parabolic, or any acceptable shape that gives predictions in substantial agreement with test results.
- Standardized stress block parameters are used for design, with defined values for the area and centroid of the equivalent stress block.
- Stresses in steel reinforcement are obtained from the representative stress-strain curve of the grade of steel being used.
- The maximum tensile strain in reinforcement at failure is required to be at least $\left(\frac{f_y}{1.15E_s} + 0.002\right)$, ensuring adequate ductility.

8. (d)

IS 456: 2000 states that when more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately.

9. (c)

As per C*l*.41.3.1 of IS 456 : 2000,

Equivalent shear force; $V_e = V_u + 1.6\frac{T_u}{b}$

$\Rightarrow$ $V_e = 0 + \frac{1.6 \times 140 \times 10^6}{350} = 640$ kN

Equivalent shear stress, $\tau_{ve} = \frac{V_e}{b \times d} = \frac{640 \times 10^3}{350 \times 750}$

$\Rightarrow$ $\tau_{ve} = 2.44$ N/mm^2

10. (c)

As per C*l*.39.1(b) of IS 456:2000,

$\text{Strain}_{\text{most compressed fibre}} = 0.0035 - 0.75\ \text{Strain}_{\text{least compressed fibre}}$

$\Rightarrow$ $0.0026 = 0.0035 - 0.75\varepsilon$

$\Rightarrow$ $\varepsilon = 0.00120$

11. (d)

For Fe415, $M_{u,\ \text{lim}} = 0.138 f_{ck} bd^2$

$= 0.138 \times 25 \times 300 \times 500^2 \times 10^{-6}$ kNm

$= 258.75$ kN-m

12. (b)

As per IS 456 : 2000, C*l* 26.5.3.1

For a concrete pedestal $\left(\frac{l_e}{D} < 3\right)$

Minimum reinforcement of longitudinal bar will be 0.15% of gross area of cross-section.

So, $A_{st,\ \text{min}} = \frac{0.15}{100} \times 400 \times 500$

$= 300$ mm^2

13. (a)

IS 456: 2000 states that for slabs spanning in two directions, the shorter of the two spans is used for calculating the span to effective depth ratios.

14. (a)

Slenderness effect of column is compensated by increasing the applied moment. So as per C*l* 39.7.1 of IS 456: 2000, additional moment,

$$M_a = \frac{P_u D}{2000}\left[\frac{l}{D}\right]^2$$

$$= \frac{2000 \times 0.5}{2000} \times (20)^2 = 200 \text{ kN-m}$$

15. (d)

As per IS 456 : 2000

- The final deflection due to all loads, including the effects of temperature, creep and shrinkage, and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.
- The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and application of finishes should not normally exceed span/350 or 20 mm, whichever is less.

16. (c)

As per IS 456 : 2000 (*Cl* 23.3)

For a cantilever beam

$$L_{clear} = \min\begin{cases}\dfrac{100\,b^2}{d}\\ 25\,b\end{cases}$$

$$\Rightarrow \quad L_{clear} = \min\begin{cases}\dfrac{100\times 300^2}{500}\text{mm} = 18\text{ m}\\ 25\times 300\text{ mm} = 7.5\text{ m}\end{cases}$$

$$\Rightarrow \quad L_{clear} = 7.5\text{ m}$$

17. (c)

18. (c)

For a masonry wall, the eccentricity ratio is defined as the ratio of the resultant eccentricity of the vertical load to the effective thickness of the wall.

This ratio helps understand how the applied load deviates from the centroid of the wall's cross-section

19. (b)

Concrete in sea-water or exposed directly along the sea-coast shall be at least M20 grade in the case of plain concrete and M30 in case of reinforced concrete.

20. (b)

Type of losses of prestress

No.	Pretensioning	No.	Post-tensioning
1.	Elastic deformation of concrete	1.	No loss due to elastic deformation if all the wires are simultaneously tensioned. If the wires are successively tensioned, there will be loss of prestress due to elastic deformation of concrete
2.	Relaxation of stress in steel	2.	Relaxation of stress in steel
3.	Shrinkage of concrete	3.	Shrinkage of concrete
4.	Creep of concrete	4.	Creep of concrete
		5.	Friction
		6.	Anchorage slip

21. **(b)**

Horizontal seismic coefficient

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

$$\Rightarrow \quad A_h = \frac{0.16}{2} \times \frac{1}{4} \times 2.5$$

$$\Rightarrow \quad A_h = 0.05$$

22. **(d)**

All the listed parameters influence the degree of damage experienced by a structure during seismic activity.

23. **(d)**

Refer IS 3370 Part-2 C*l*. 8.1.1

24. **(b)**

25. **(d)**

Refer IS 456 : 2000 (C*l*.26.5.3.2).

26. **(c)**

The limit state method of design aims to ensure adequate safety at ultimate loads as well as adequate serviceability at service loads by considering all relevant limit states. Ultimate limit states relate to collapse or failure modes such as loss of strength, overturning, sliding, buckling, and fatigue fracture. Serviceability limit states concern discomfort to occupants or malfunction of the structure due to excessive deflection, crack-width, vibration, leakage, and loss of durability.

27. **(a)**

Due to the pre-compression introduced in prestressed concrete and the reduction in shear stress caused by the component of prestressing force in a curved cable, the principal tensile stress in prestressed concrete becomes lower than that in reinforced concrete. As a result, the shear resistance of prestressed concrete can be increased, allowing the use of thin webs and a smaller amount of shear reinforcement.

28. **(a)**

Eccentrically prestressing the member causes deflections opposite to that caused due to applied loads. Hence by properly choosing the prestress, the deflection of the member can be reduced or even completely eliminated. Due to the above reasons, when compared with reinforced concrete, prestressed concrete requires smaller sections. Hence, prestressed concrete members are lighter and have more aesthetic appeal. Prestressed concrete not only saves material, it also reduces dead load. This aspect makes it the most preferred construction method for long-span structures like bridges where dead load is a significant part of the total design load.

29. **(a)**

Refer IS 456 : 2000 Table-28 for effective length of compression member.

30. (b)

Refer Cl. 26.2.1.2 of IS 456 : 2000.

31. (d)

For lateral load-resisting members, positive reinforcement must be fully anchored into the support for a length equal to development length from the face of support.

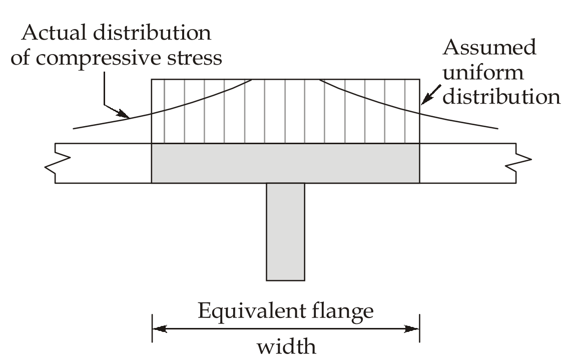
32. (d)

Bending Moment Coefficients				
	Span moments		Support moments	
Type of load	**Near middle of end span**	**At middle of interior span**	**At support next to the end support**	**All other interior supports**
Dead and imposed load fixed)	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

33. (d)

Bends and hooks are ineffective in anchoring bars in compression. Hence, IS 456 : 2000 (Clause 26.2.2.2) specifies that for bars in compression, only the projected length of hooks, bends and straight lengths beyond bends shall be considered for development length. However, for bars in compression, it is doubtful whether extensions beyond bends can meaningfully provide anchorage.

34. (a)

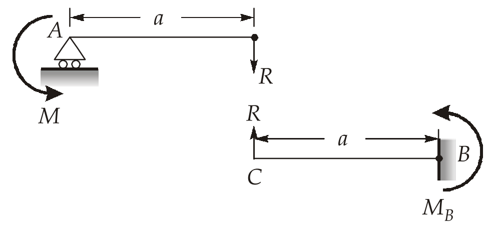


35. (d)

Consideration of shear in columns is usually neglected because the shear stresses are generally low and the shear resistance is very high on account of the presence of axial compression and the presence of lateral reinforcement.

Section B : Structural Analysis-I

36. (b)



$$\Sigma M_A = 0$$

$$\Rightarrow \quad R \times a = M$$

$$\Rightarrow \quad R = \frac{M}{a}$$

Moment at B, $M_B = Ra = \frac{M}{a} \times a = M$ (Anticlockwise)

37. (c)

Fixed-end moment for a concentrated mid-span load on a prismatic span,

$$M_{FBC} = \frac{-WL}{8} = \frac{-8 \times 4}{8} = -4 \text{ kN-m}$$

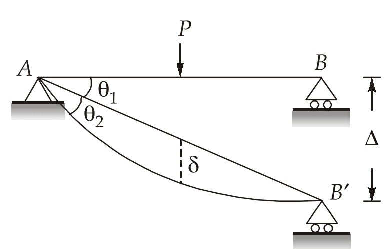
Slope-deflection relation,

$$M_{BC} = M_{FBC} + \frac{2EI}{L}\left(2\theta_B + \theta_C - \frac{3\Delta}{L}\right)$$

$$\Rightarrow \quad M_{BC} = -4 + \frac{2(2EI)}{4}(2\theta_B + \theta_C)$$

$$\Rightarrow \quad M_{BC} = -4 + EI(2\theta_B + \theta_C)$$

38. (b)



From the diagram,

$$\theta_1 = \frac{\Delta}{L} = \frac{PL^2}{24EI}$$

$$\theta_2 = \frac{PL^2}{16EI}$$

$$\therefore \quad \theta = \theta_1 + \theta_2 = \frac{PL^2}{24EI} + \frac{PL^2}{16EI}$$

Since, slope at A is zero, it can be assumed to be fixed,

$$\therefore \quad \theta = \frac{ML}{3EI}$$

$$\Rightarrow \quad \frac{ML}{3EI} = \frac{PL^2}{24EI} + \frac{PL^2}{16EI}$$

$$\Rightarrow \quad \frac{ML}{3EI} = \frac{5PL^2}{48EI}$$

$$\Rightarrow \quad M = \frac{5PL}{16}$$

39. (b)

$$\text{Stiffness of joint } B,\ K_T = \frac{4(2EI)}{6} + \frac{3EI}{4} = \frac{25}{12}EI$$

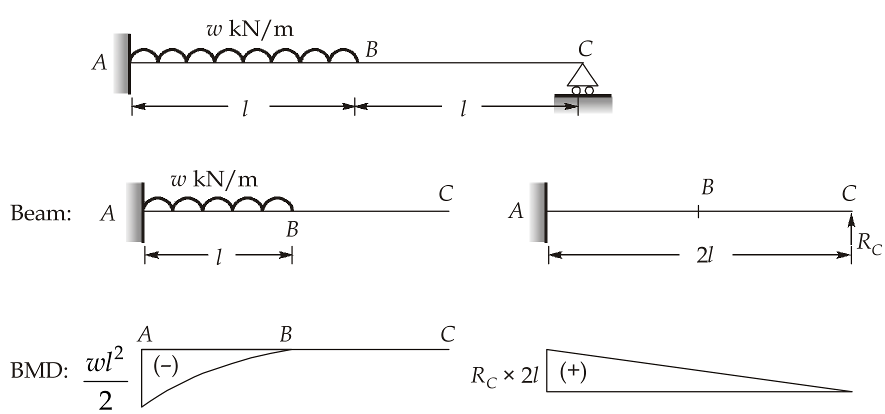
Moment, $$M_B = K_T\theta_B$$

$$\Rightarrow \quad \theta_B = \frac{M_B}{K_T} = \frac{M}{\frac{25}{12}EI}$$

$$\Rightarrow \quad \theta_B = \frac{12M}{25EI}$$

40. (c)

Let the beam be split as below.



The moment of $\frac{M}{EI}$ diagram between A and C about C is zero as deflection at C is zero.

$$\therefore \quad \frac{wl^2}{2EI} \times \frac{l}{3}\left(\frac{3}{4}l + l\right) - \frac{R_C \times 2l}{EI} \times \frac{2l}{2} \times \frac{2}{3} \times 2l = 0$$

$$\Rightarrow \quad \frac{wl^2}{2} \times \frac{7l}{4} = \frac{8l^3 R_c}{3EI}$$

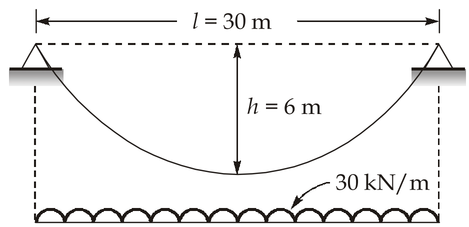
$$\Rightarrow \quad R_C = \frac{7wl}{64} \text{ and } R_A = \frac{57wl}{64}$$

Substituting values,

$$R_C = \frac{7\times 4\times 2}{64} = \frac{7}{8}\ \text{kN}\ (\uparrow)$$

$$R_A = 8-\frac{7}{8} = \frac{57}{8}\ \text{kN}\ (\uparrow)$$

41. (a)



$$\text{Curved length} = l+\frac{8h^2}{3l} = 30+\frac{8}{3}\left(\frac{6^2}{30}\right) = 33.2\ \text{m}$$

42. (d)

Total stiffness at joint A,

$$k_A = k_{AB}+k_{AC}+k_{AD}+k_{AE}+k_{AF}$$

Stiffness at A,

$$k_A = \frac{3(2EI)}{2l}+\frac{4(2EI)}{l}+0+0+\frac{EI}{l}$$

$$\Rightarrow \quad k_A = \frac{12EI}{l}$$

$\therefore$ Moment required for unit rotation at joint $A = k_A \times \theta_A = \frac{12EI}{l}\times 1 = \frac{12EI}{l}$

43. (d)

Fixed end moments

$$M_{FAC} = -\frac{25 \times 3^2 \times 2}{5^2} = -18 \text{ kN-m}$$

$$M_{FCA} = +\frac{25 \times 3 \times 2^2}{5^2} = +12 \text{ kN-m}$$

$$M_{FCB} = -\frac{12(5)^2}{12} = -25 \text{ kN-m}$$

$$M_{FBC} = +\frac{12(5)^2}{12} = +25 \text{ kN-m}$$

Joint	Member	Stiffness	Total stiffness	D.F.
C	CA	$\frac{4EI}{5}$	$\frac{7EI}{5}$	$\frac{4}{7}$
	CB	$\frac{3EI}{5}$		$\frac{3}{7}$

	A	C	C	B
D.F.		$\frac{4}{7}$	$\frac{3}{7}$	
F.E.M.	– 18	+ 12	–25	25
			–12.5	–25
	– 18	12	$-\frac{75}{2}$	0
		$\frac{102}{7}$	$\frac{153}{14}$	
	$\frac{51}{7}$			0
		$\frac{186}{7}$	$-\frac{186}{7}$	

44. (b)

Number of members, $m = 12$

Number of joints, $j = 11$

Number of external support reactions, $R_e = 8$

Degree of static indeterminacy for 2D frame is given by

$$D_s = (3m + R_e) - (3j + r_r)$$

where,

$$r_r = \Sigma(m' - 1) = 4 - 1 = 3$$

$$\therefore \quad D_s = (3 \times 12 + 8) - (3 \times 11 + 3)$$

$$\Rightarrow \quad D_s = 8$$

45. (b)

$$\text{Fixed end moment at } A = \frac{Pab^2}{L^2}$$

$$\Rightarrow \quad M_{FAB} = \frac{10\cos 30° \times 3 \times 4^2}{7^2}$$

$$\Rightarrow \quad M_{FAB} = \frac{10 \times \frac{\sqrt{3}}{2} \times 3 \times 4^2}{7^2}$$

$$\Rightarrow \quad M_{FAB} = 8.48 \text{ kN-m}$$

46. (a)

Using Maxwell - Betti's theorem,

$$200 \times \delta_D = 50 \times \delta_B + 100\,\delta_C$$

$$\Rightarrow \quad \delta_D = \frac{50 \times 8 + 100 \times 12}{200} = \frac{400 + 1200}{200}$$

$$\Rightarrow \quad \delta_D = 8 \text{ mm}$$

47. (d)

48. (a)

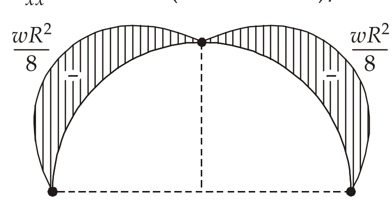
3-hinged semicircular arch of radius R carries a uniformly distributed load of w per unit length over entire span.

$$H = wR/2$$

$$V_A = V_B = wR$$

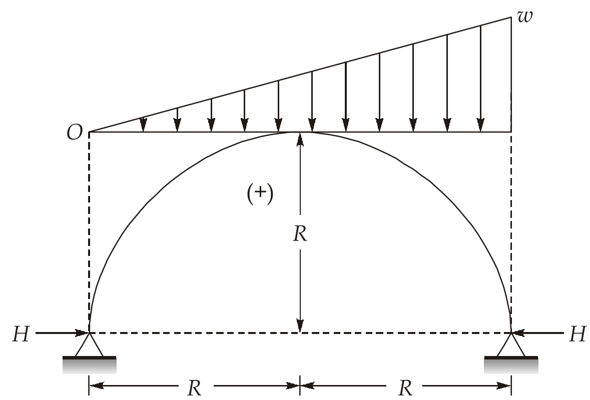
Bending moment at any section x-x

$$BM_{xx} = -\,wR^2(\sin\theta - \sin^2\theta)/2$$



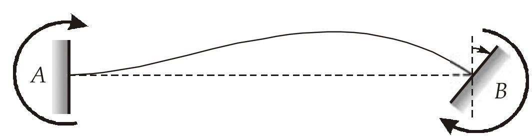
Bending moment diagram

49. (a)



Horizontal thrust, $$H = \frac{2wR}{3\pi}$$

50. (d)



Section C : CPM PERT-II + Hydrology and Water Resource Engg-II

51. (b)

A contract is treated as invalid when consent is obtained through force or threats. Such situations fall under duress, and in these cases, the party applying the pressure is also liable for legal punishment. Misrepresentation, on the other hand, makes the contract invalid without imposing punishment, since the incorrect statement is made innocently or without intent to deceive. Contracts that deal with subjects violating public policy are void irrespective of the agreement between the parties; mutual consent cannot validate an agreement that conflicts with public policy.

52. (b)

All the expenses related to the contractor's office and establishment are termed as general overhead, which is a recurring expenditure and does not depend upon the volume of the work under execution.

53. (a)

A tender is treated as informal when it is not submitted on the proper form, is not accompanied by earnest money, or is not correctly filled in. Unbalanced tendering occurs when a contractor deliberately quotes higher rates for items expected to rise in quantity and lower rates for items expected to reduce or will not execute at all, based on anticipation or external information. Global tenders, however, are issued for large or highly specialised works and invite bids worldwide; they are not restricted to item-rate contracts within the country.

54. (a)

$$\text{Initial cost} = \text{Rs.}18400$$

$$\text{Salvage value} = \frac{1}{10}\times 18400 = \text{Rs.}1840$$

$$\text{Annual depreciation, } D = \frac{18400-1840}{8} = \text{Rs.}2070$$

55. (d)

The security deposit required under the contract is recovered gradually through running bills, normally at a rate of 10%, until the full amount stipulated is reached. An extension of time can be granted when the delay is not due to the contractor's lapse and the authority is satisfied with the reasons submitted. Secured advance allows the contractor to obtain up to 75% of the estimated value of materials brought to the site, subject to departmental conditions. Work that is likely to be concealed must not be covered without giving a minimum notice period of seven days to enable inspection by the authority.

56. (c)

Unsafe acts refer to worker behaviours that deviate from established safe practices and often trigger avoidable incidents on site.

57. (d)

Functions of Break-Even Chart:

- Provides a clear view of the business position by showing the no-profit and no-loss point.
- Helps understand how variations in fixed cost, variable cost and revenue affect profitability.
- Indicates margin of safety and angle of incidence, reflecting business stability.
- Assists management in decision-making by showing likely profit or loss at different output levels.

Limitations of Break-Even Chart:

- Market conditions and capacity variations make cost classification into fixed and variable difficult, reducing accuracy.
- Total cost and revenue lines may not remain straight in practice as costs do not vary proportionally.
- Represents only a static, short-run picture, whereas business conditions are dynamic.
- Becomes less effective when a company deals with multiple products, making analysis complex.

58. (a)

In an item rate contract, the contractor is paid strictly according to the detailed measurements of the actual quantities executed. In a cost-plus-fixed-fee contract, the fee paid to the contractor remains constant irrespective of the actual construction cost, since it is a predetermined lump-sum amount. A lump-sum contract generally eliminates the need for detailed measurements except where changes or additions arise beyond the original drawings and specifications. In the cost plus sliding or fluctuating fee-scale system, the contractor's percentage fee reduces progressively as the actual construction cost increases, aligning both parties toward minimising total expenditure.

59. (d)

The sinking fund depreciation model is based on the assumption that the asset's value reduces at an increasing rate over its life.

60. (d)

Rolling resistance offered by haul road = 20 × 40 = 800 kg

$$\text{Load on driving tyres} = \frac{60}{100} \times 20000 = 12000 \text{ kg}$$

Maximum possible rimpull before slippage of tyres = Coefficient of traction × Load on driving tyres

$$= 0.70 \times 12000 = 8400 \text{ kg}$$

$$\therefore \quad \text{Maximum tractive effort} = 8400 - 800 = 7600 \text{ kg}$$

61. (a)

Initially, boron is useful for the growth of the crops, but its concentration above 0.3 ppm may be toxic to the plants.

62. (d)

Qualities of a good siphon spillway:

- It should have quick priming with automatic start of operation.
- Priming depth should be low so that it functions even with small rise of water level above crest.
- No knocking should occur during priming or deperming, and flow should remain steady.
- The siphon should be self-cleansing to avoid silt or debris deposition.
- Air should not enter the siphon bore, and dissolved air should not separate due to negative pressure.
- The flow should be smooth, free of vibrations, and overall efficiency should be high.
- Maintenance cost should be low, and design should be simple and easy to construct.

Limitations of siphon spillway:

- Construction is expensive and the discharging capacity is limited.
- Sudden incidence of flood water may occur downstream due to siphonic action.
- Large floating debris may block the outlet.
- Excessive vibrations may develop during priming, requiring strong structural support.
- Cavitation may occur for high head differences, especially when exceeding about 7.5 m.
- Repair and maintenance are difficult, and performance may be affected by cracks or erratic siphonic action.

63. (d)

Conditions favouring the adoption of sprinkler irrigation:

- It is preferred when the land topography is irregular or unsuitable for surface irrigation.
- The method suits situations where the land gradient is steep and soil is easily erodible.
- Sprinklers are useful when the soil is excessively permeable or highly impermeable, making surface distribution difficult.
- A high watertable favours this method, as sprinkling avoids waterlogging.
- It is also adopted in areas where the seasonal water requirement is low, such as coastal zones.
- The method suits crops needing humidity control, shallow-rooted crops, or those requiring frequent irrigation.
- Sprinkler irrigation becomes advantageous when water availability is difficult and scarce.

64. (a)

Dates	Consumptive use (mm)	Effective rainfall (mm)	NIR = C_u-R_e (mm)
24-31 October	28	23	5
01-30 November	86.5	15.1	71.4
01-31 December	157.2	6.6	150.6
01-31 January	190.4	3.9	186.5
01-04 February	11.9	1.4	10.5
			Σ = 424mm

∴ Net irrigation requirement = 424 mm = 42.4 cm

65. (d)

(i) $v = \sqrt{\frac{2}{5} fR}$

(ii) $Af^2 = 140\, v^5$

(iii) $Qf^2 = 140\, v^6$

(iv) $v = 10.8\, R^{2/3}\, S^{1/3}$

(v) $P = 4.75\sqrt{Q}$

(vi) $f = 176\sqrt{d_{mm}}$

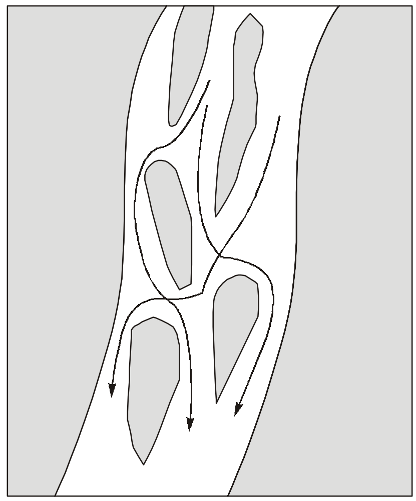
(vii) $S = \left(\frac{f^{5/3}}{3340Q^{1/6}}\right)$

66. (b)

Border flooding is a surface irrigation method in which the land is divided into long, narrow strips separated by low levees called borders. Water is released from a supply ditch and flows down the strip, infiltrating into the soil as it advances. The strips are typically 10 to 20 metres wide and 100 to 400 metres long, and the land is levelled perpendicular to the direction of flow to ensure uniform distribution. Ridges between borders prevent overtopping, while the discharge required depends on the soil's infiltration characteristics, with coarse soils needing higher discharge and fine soils requiring smaller flows to avoid losses.

67. (b)

A braided river develops when the sediment load carried by the river exceeds its transport capacity under existing flow conditions. The excess coarse material is deposited within the channel, forming mid-channel bars or alluvial islands. As these deposits grow, the river flow is forced to split and pass around them, creating multiple shifting channels that continually divide and re-join.



68. (d)

Given:

$$H = 4.4 \text{ m}$$
$$b = 3.32 \text{ m}$$
$$d = 4 \text{ m}$$

We know,

$$\lambda = \frac{1}{2}\left[1 + \sqrt{1 + \left(\frac{b}{d}\right)^2}\right]$$

$$\Rightarrow \quad \lambda = \frac{1}{2}\left[1 + \sqrt{1 + \left(\frac{3.32}{4}\right)^2}\right]$$

$$\Rightarrow \quad \lambda = \frac{1}{2}\left[1 + \sqrt{1 + 0.6889}\right] = \frac{1}{2}\left[1 + \sqrt{1.6889}\right]$$

$$\Rightarrow \quad \lambda \approx \frac{1}{2}\left[1 + \sqrt{1.69}\right] = 1.15$$

Khosla's safe exit gradient,

$$G_E = \frac{H}{d} \cdot \frac{1}{\pi\sqrt{\lambda}}$$

$$\Rightarrow \quad G_E = \frac{4.4}{4 \times \frac{22}{7} \times \sqrt{1.15}}$$

$$\because \quad \sqrt{115} = 10.7$$

$$\therefore \quad \sqrt{1.15} = 1.07$$

$$\therefore \quad G_E = 0.33$$

69. (d)

70. (c)

The regime equations were developed using data from channels that carried relatively low sediment loads, roughly around 500 ppm. Because of this, the equations reflect conditions where sediment load was not large enough to significantly alter channel shape, and therefore take into account mainly the water discharge and sediment size, but not the full effects of varying sediment transport. Even with this limitation, the regime relations provide useful guidance in the design of unlined channels and river training works.

71. (a)

We know, field capacity, $F = \frac{\gamma_w}{\gamma_d} n$

$$\Rightarrow \quad \frac{\gamma_d}{\gamma_w} = \frac{n}{F}$$

$$\Rightarrow \quad \frac{\gamma_d}{\gamma_w} = \frac{0.40}{0.32} = 1.25$$

$$\text{Maximum water stored} = \frac{\gamma_d}{\gamma_w} d\,(F - P)$$

$$= 1.25 \times 0.75 \times (0.32 - 0.12)$$

$$= 0.1875 \text{ m}$$

Deficiency of water created before irrigation is done

$$= 0.60 \times 0.1875 = 0.1125 \text{ m}$$

Volume of irrigation water required to fill up deficiency

$$= 0.8 \times 0.1125 = 0.09 \text{ ha-m}$$

$$\therefore \quad \text{Efficiency of field application} = \frac{0.09}{0.09} = 1 = 100\%$$

72. (a)

Given: $V = 49$ km/hr; $F = 16$ km < 32 km

Height of wave,

$$h_w = 0.032\sqrt{V.F} + 0.763 - 0.271\, F^{1/4}$$

$$\Rightarrow \quad h_w = 0.032\sqrt{49 \times 16} + 0.763 - 0.271 \times 16^{1/4}$$

$$\Rightarrow \quad h_w = 0.032\sqrt{784} + 0.763 - 0.271 \times 2$$

$$\Rightarrow \quad h_w = 0.032 \times 28 + 0.763 - 0.542$$

$$\Rightarrow \quad h_w = 1.117 \text{ m}$$

73. (a)

Cross-drainage works are constructed where an irrigation canal and a natural drainage or stream intersect. The arrangement adopted depends on the relative bed levels of the two channel and drain:

(i) When the canal bed lies higher, the canal is carried over the drain by an aqueduct or, if water cannot pass freely below, by a siphon aqueduct.

(ii) When the drain bed lies higher, the drain is taken over the canal through a super passage or by a siphon super passage if the canal water must pass below under pressure.

(iii) If both beds are nearly at the same level, a level crossing is provided, allowing the canal and drainage to intersect at grade.

74. (d)

The ejector should be situated neither too close nor too far from the head regulator. If the ejector is located too near the regulator, most of the particles will remain in suspension due to residual turbulence and their desired ejection might not be achieved. If the ejector is located too far downstream of the regulator, the sediment may get deposited between the ejector and the regulator, reducing the channel capacity.

75. (a)

The resultant of all forces acting on the dam should remain within the middle-third of the base width of the dam to avoid overturning. There should also be no tension in the dam section to avoid the formation of cracks. This can only be achieved by maintaining the middle-third rule.

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