DETAILED SOLUTIONS

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# ESE 2025 : Prelims Exam

CLASSROOM TEST SERIES

**CIVIL ENGINEERING**

**Test 22**

## ANUBHAV - PAPER-II

**Simulate Real ESE Prelims Exam**

**Full Syllabus Test**

### Answer Key

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

***Q.21 :** *Marks will be awarded to all. [None of the options are correct.]*
***Q.32 :** *Answer has been Updated.*

## DETAILED EXPLANATIONS

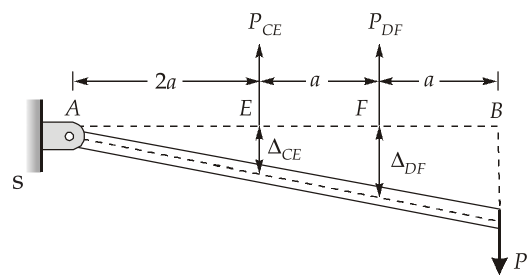
**1. (b)**

Taking moments about $A$,

$$P_{CE} \times 2a + P_{DF} \times 3a - P \times 4a = 0$$

$$\Rightarrow \quad 2P_{CE} + 3P_{DF} = 4P \qquad \text{...(i)}$$

Deflected shape is shown below.




$$\frac{\Delta_{CE}}{2a} = \frac{\Delta_{DF}}{3a}$$

$$\Rightarrow \quad 3\left(\frac{P_{CE}l}{AE}\right) = 2\left(\frac{P_{DF}l}{AE}\right)$$

$$\Rightarrow \quad 3P_{CE} = 2P_{DF} \qquad \text{...(ii)}$$

From equation (i) and (ii)

$$2P_{CE} + 3\left(\frac{3P_{CE}}{2}\right) = 4P$$

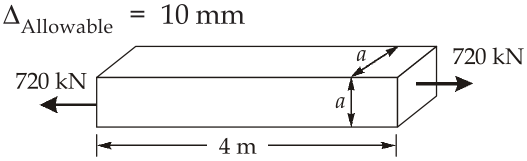
$$\Rightarrow \quad \frac{13}{2}P_{CE} = 4\text{P}$$

$$\Rightarrow \quad P_{CE} = \frac{8P}{13}$$

**2. (a)**

Given:

$$\Delta_{\text{Allowable}} = 10 \text{ mm}$$




Elongation of bar

$$\Delta \le \Delta_{\text{allowable}}$$

$$\Rightarrow \quad \frac{720 \times 10^3 \times 4000}{A \times 72 \times 10^3} \le 10$$

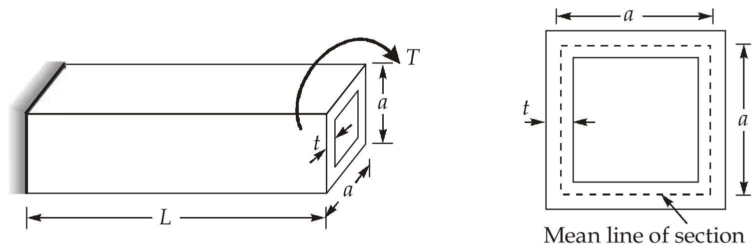
$$\Rightarrow \quad A \ge 4000 \text{ mm}^2$$

$$\Rightarrow \quad a^2 \ge 4000 \text{ mm}^2$$

$$\therefore \quad a_{\text{min}} = 20\sqrt{10} = 20 \times 3.16$$

$$\Rightarrow \quad a_{\text{min}} = 63.2 \text{ mm}$$

**3. (d)**




Angle of twist in thin tube is given by

$$\theta = \frac{TL}{4GA_m^2}\int \frac{dS}{t} \qquad \text{...(i)}$$

where, $A_m$ = Area enclosed by mean line of section

$$A_m = a^2 \qquad (\because a >> t)$$

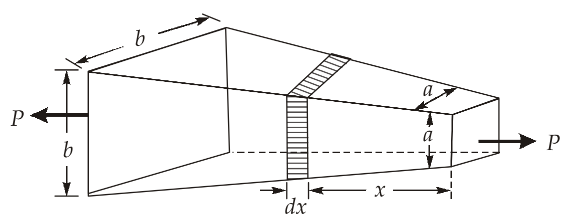
$$\int \frac{dS}{t} = \frac{4a}{t}$$

From equation (i)

$$\theta = \frac{TL}{4Ga^4} \times \frac{4a}{t}$$

$$\theta = \frac{TL}{Ga^3 t}$$

**4. (a)**




Elongation of elemental strip $= \dfrac{Pdx}{A_x E}$

where, $A_x = b_x \times b_x = \left[a + \left(\dfrac{b-a}{l}\right)x\right]^2$

Total elongation of bar

$$\Delta = \int_0^l \frac{Pdx}{A_x E} = \int_0^l \frac{Pdx}{\left[a + \left(\frac{b-a}{l}\right)x\right]^2 E}$$

$$\Rightarrow \qquad \Delta = \frac{P}{E}\left[\frac{-1}{a + \left(\frac{b-a}{l}\right)x}\right]_0^l \times \frac{1}{\left(\frac{b-a}{l}\right)}$$

$$\Rightarrow \quad \Delta = \frac{Pl}{E(b-a)}\left[\frac{-1}{b}+\frac{1}{a}\right]$$

$$\Rightarrow \quad \Delta = \frac{Pl}{abE}$$

$$\Rightarrow \quad \Delta = \frac{400\times 10^3 \times 2000}{20\times 40\times 2\times 10^5}$$

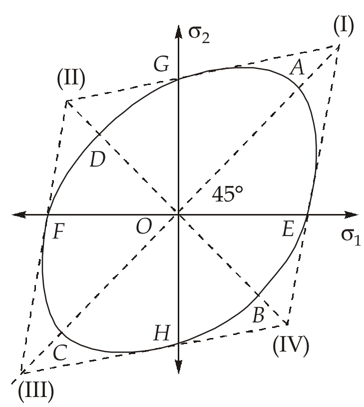
$$\Rightarrow \quad \Delta = 5 \text{ mm}$$

**5. (c)**

For two dimensional case, the maximum strain energy theory is represented as:

$$\sigma_1^2+\sigma_2^2-2\mu\sigma_1\sigma_2 = \left(\frac{\sigma_y}{FOS}\right)^2$$

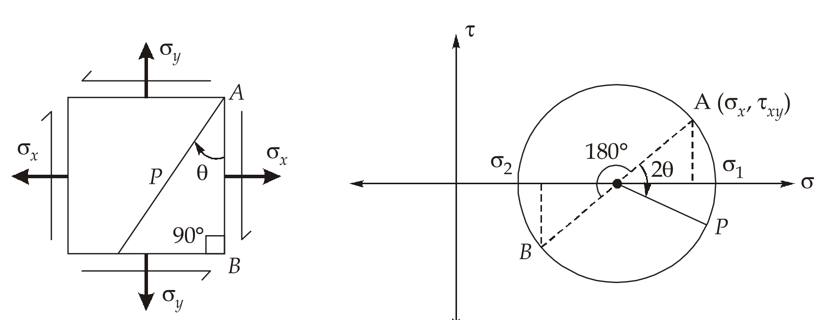
This is the equation of an ellipse with centre at origin and axis inclined at 45° as shown in figure.




**6. (d)**

- The shear center is defined as the point where a transverse load can be applied without causing the beam to twist. This is crucial in design to avoid torsional stresses.
- In doubly symmetric sections (e.g. I-beams) the shear center coincides with the centroid of the section and it always lies on axis of symmetry.

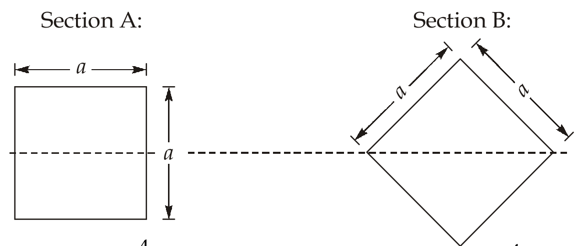
**7. (d)**




- A rotation of 2θ on Mohr's circle corresponds to a physical rotation of θ in the actual stress element.

- Points on Mohr's circle that are 180° apart represent perpendicular faces of the same stress element.

**8. (c)**




$$(I_{xx})_A = \frac{a^4}{12} \qquad (I_{xx})_B = \frac{a^4}{12}$$

From bending equation

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

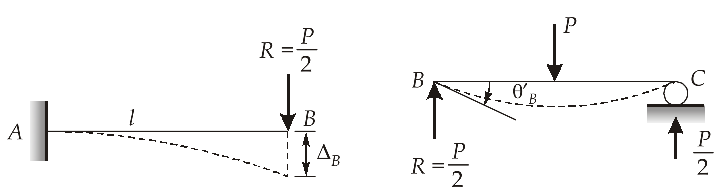
$$\therefore \quad \text{Curvature } \rho = \left(\frac{1}{R}\right) = \frac{M}{EI}$$

$$\therefore \quad \rho \propto \frac{1}{I}$$

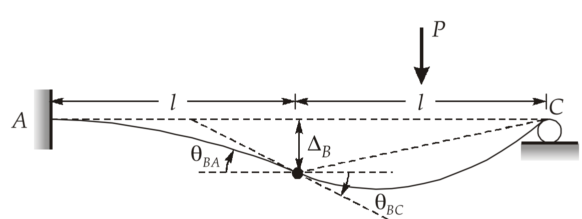
Area moment of inertia about neutral axis is same.

$$\therefore \quad \text{Curvature, } \rho_A = \rho_B$$

**9. (b)**




Deflected shape of beam.




$$\Delta_B = \frac{Rl^3}{3EI} = \frac{Pl^3}{6EI} \qquad \text{(Downward)}$$

Slope at B for BA portion,

$$\theta_{BA} = \frac{Rl^2}{2EI} = \frac{Pl^2}{4EI} \qquad \text{(Clockwise)}$$

Slope at B for BC portion,

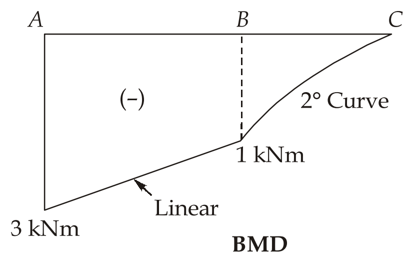
$$\theta_{BC} = \theta_B' - \frac{\Delta_B}{l} = \frac{Pl^2}{16EI} - \frac{Pl^2}{6EI}$$

$$\Rightarrow \qquad \theta_{BC} = \frac{-5}{48}\left(\frac{Pl^2}{EI}\right)$$

$$\Rightarrow \qquad \theta_{BC} = \frac{5}{48}\left(\frac{Pl^2}{EI}\right) \qquad \text{(Anticlockwise)}$$

**10. (d)**

There is no load on portion AB, so shear force remains constant throughout AB. Therefore, the shape of BMD between AB will be linearly varying with maximum value at A.




**BMD**

**11. (b)**

As $$\tau = \frac{V}{2I}\left(\frac{d^2}{4} - y^2\right) = \frac{6V}{bd^3}\left(\frac{d^2}{4} - y^2\right)$$

$$\tau_{avg} = \frac{V}{bd}$$

According to question, $$\tau = \tau_{avg}$$

$$\Rightarrow \qquad \frac{V}{bd} = \frac{6V}{bd^3}\left(\frac{d^2}{4} - y^2\right)$$

$$\Rightarrow \qquad \frac{6}{d^2}\left(\frac{d^2}{4} - y^2\right) = 1$$

$$\Rightarrow \qquad y^2 = \frac{d^2}{4} - \frac{d^2}{6} = \frac{3d^2 - 2d^2}{12} = \frac{d^2}{12}$$

$$\Rightarrow \qquad y = \frac{d}{2\sqrt{3}}$$

**12. (b)**

Additionally, flexure formula is not applicable when section is not symmetrical about plane of bending, in such a case, we require to calculate, principal axes principal moment of inertia and product moment of inertia, and the stress values will be dependent on these parameters.

So in order to void twisting, the plane of bending should pass through shear center.

**13. (b)**

**14. (c)**

Total static indeterminacy for 2D frame

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

where, $m$ = Number of members = 8

$j$ = Number of joints = 8

$R_e$ = External support reactions = 8

$r_r$ = 0

$D_s = 3 \times 8 + 8 - 3 \times 8$

$\Rightarrow \quad D_s = 8$

External indeterminacy, $D_{se} = R_e - 3 = 8 - 3 = 5$

Internal indeterminacy, $D_{si} = D_s - D_{se} = 8 - 5 = 3$

**Alternate solution**:

Internal indeterminacy, $D_{si} = 3C - r_r$

where, $C$ = Number of closed loops

$\therefore \quad D_{si} = 3 \times 1 - 0$

$\Rightarrow \quad D_{si} = 3$

**15. (c)**

**Effect of rotation of supports**: In continuous beams, support rotation (like at the ends or intermediate supports) affect how moments are distributed. This happens through moment distribution methods, where support rotations change the stiffness distribution and thus affect BM and SF values.

**Effect of settlement of supports**: Support settlement (downward or upward vertical displacement) creates additional moment and shear in the beam due to compatibility condition even if there are no loads applied, differential settlement can cause internal stresses.

**16. (d)**

Slope deflection equation

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

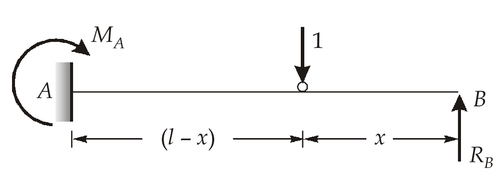
$$M_{FBC} = \frac{-15 \times 8^2}{12} = -80\,\text{kNm}$$

$$\therefore \quad M_{BC} = -80 + \frac{2 \times EI}{8}(2\theta_B + \theta_C)$$

$$\Rightarrow \quad M_{BC} = -80 + 0.25EI(2\theta_B + \theta_C)$$

$$\Rightarrow \quad M_{BC} = -80 + 0.5EI(\theta_B + 0.5\theta_C)$$

**17. (a)**




Deflection at point, $B = 0$

$$\Rightarrow \quad \frac{1(l-x)^3}{3EI} + \frac{1(l-x)^2}{2EI}x - \frac{R_B l^3}{3EI} = 0$$

$$\Rightarrow \quad R_B = \frac{(l-x)^3}{l^3} + \frac{3(l-x)^2 x}{2l^3}$$

Taking moments about '$A$'

$$-M_A + R_B l - 1 \times (l - x) = 0$$

$$\Rightarrow \quad M_A = \left[\frac{(l-x)^3}{l^3} + \frac{3(l-x)^2 x}{2l^3}\right] l - (l-x)$$

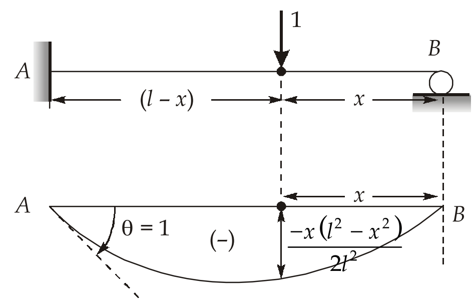
$$\Rightarrow \quad M_A = \frac{(l-x)}{2l^2}\left[2(l-x)^2 + 3x(l-x) - 2l^2\right]$$

$$\Rightarrow \quad M_A = \frac{(l-x)}{2l^2}\left(-x^2 - lx\right) = \frac{-x(l-x)}{2l^2}(l+x)$$

$$\Rightarrow \quad M_A = \frac{-x\left(l^2 - x^2\right)}{2l^2}$$

**Note**:

**Alternatively**:




ILD for BM at $A$

**Option (a):**

$$y = \frac{-x\left(l^2 - x^2\right)}{2l^2}$$

$$\frac{dy}{dx} = \frac{-\left(l^2 - 3x^2\right)}{2l^2}$$

$$\therefore \quad \left(\frac{dy}{dx}\right)_{\text{at } x=l} = \frac{-\left(l^2 - 3l^2\right)}{2l^2} = +1$$

**Option (b):**

$$\left(\frac{dy}{dx}\right)_{\text{at } x=l} = \frac{-\left(l^2 - 3l^2\right)}{3l^2} = \frac{+2}{3} \neq 1$$

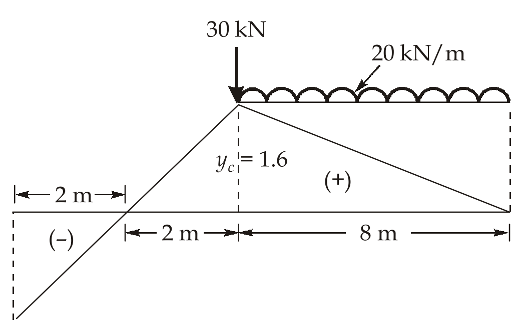
**Option (c):**

$$\left(\frac{dy}{dx}\right)_{\text{at } x=l} = \frac{-\left(l^2 - 3l^2\right)}{l^2} = 2 \neq 1$$

$\left(\frac{dy}{dx}\right)_{\text{at } x=l}$ of equation given in option (a) is unity. So option (a) is correct.

**18.** **(d)**

Using Muller's Breslau principle




ILD for BM at C

Maximum bending moment at $C$,

$$(BM)_{c,\ max} = \left(\frac{1}{2}\times1.6\times8\right)\times20+30\times1.6$$
$$= 176 \text{ kNm}$$

**19. (a)**

| Joint | Member | Stiffness | Total stiffness | D.F. |
|---|---|---|---|---|
| A | AB | $\frac{4EI}{4} = EI$ | $\frac{15\ EI}{4}$ | $\frac{4}{15}$ |
| | AC | $\frac{3EI}{3} = EI$ | | $\frac{4}{15}$ |
| | AD | $\frac{4EI}{4} = EI$ | | $\frac{4}{15}$ |
| | AE | $\frac{3EI}{4}$ | | $\frac{3}{15}$ |

Moment in member AB at $A$ = $M_A \times (DF)_{AB}$

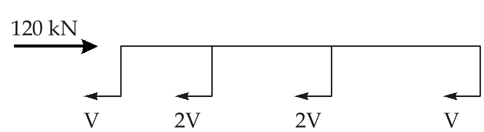
$$= 300\times\frac{4}{15} = 80 \text{ kN-m}$$

Moment in member $AB$ a $B$ = 80 × (COF)

= 80 × 0.5 = 40 kNm

**20. (b)**

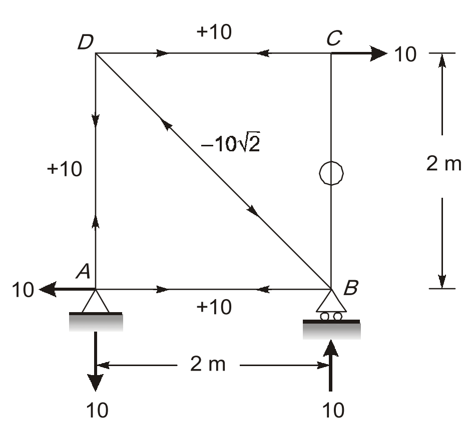
**Portal method:** It assumes that interior columns carry twice the shear force as that carried by exterior columns and that points of inflection occur at the mid-height of columns and the mid-span of beams.




$$6V = 120$$

$\Rightarrow$ $V = 20$ kN

**21. (*)**



| | $P$ | $k$ | $L$ | $PkL$ |
|---|---|---|---|---|
| $AB$ | 10 | 1 | 2 | 20 |
| $BC$ | 0 | 0 | 2 | 0 |
| $CD$ | 10 | 1 | 2 | 20 |
| $DA$ | 10 | 1 | 2 | 20 |
| $BD$ | $-10\sqrt{2}$ | $-\sqrt{2}$ | $2\sqrt{2}$ | $40\sqrt{2}$ |
| | | | | $\sum PkL = \left(60 + 40\sqrt{2}\right)$ |

Using virtual work method, $\Delta_C = \dfrac{\sum PkL}{AE}$

where, $k$ is the force in members due to unit load at $C$ in direction of deflection.

$$k = \frac{P}{10}$$

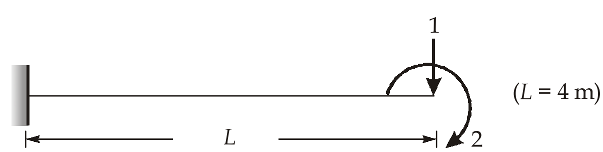
$$\therefore \quad \Delta_C = \frac{(10 \times 1 \times 2) \times 3 + \left(-10\sqrt{2} \times \left(-\sqrt{2}\right) \times 2\sqrt{2}\right)}{AE}$$

$$= \frac{\left(60 + 40\sqrt{2}\right)}{12000} = \left(\frac{3 + 2\sqrt{2}}{600}\right) \text{m}$$

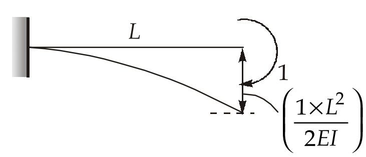
**22. (c)**

Slope deflection method and moment distribution method both are displacement method.

**23. (a)**




$f_{12}$ = Deflection in coordinate direction 1 due to unit load applied in coordinate direction 2.




$$f_{12} = \frac{L^2}{2EI} = \frac{(4)^2}{2EI} = \left(\frac{8}{EI}\right)$$

**24. (a)**

We know that for fixed beam with central load $W$, central deflection,

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

$$\therefore \quad \text{Stiffness, } k = \frac{W}{\delta} = \frac{192EI}{L^3}$$

$$\therefore \quad \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{kg}{W}} = \sqrt{\frac{192EIg}{WL^3}}$$

**25. (c)**

$$\text{Coefficient of hardness} = \frac{\text{(Loss in weight in gm)}}{3}$$

$$\text{Loss in weight} = 480 - 464 = 16 \text{ gm}$$

$$\text{Coefficient of hardness} = 20 - \frac{16}{3} = 14.67$$

**NOTE**:
- For a good aggregate, it should not be less than 17.
- For medium quality aggregate it is between 14 to 17.
- Aggregates having a coefficient of hardness less than 14 are termed as soft and are used for road work.

**26. (a)**
- Star shakes occur when the outer layers of timber dry and shrink faster than the inner ones.
- This causes radial cracks that start at the bark and move toward the pith (center).
- It's a common defect during improper or rapid seasoning of timber.

**27. (a)**
Aggregate from igneous rock are satisfactory because they are normally hard, tough and dense. However, the metamorphic rock which exhibits foliated structure is not suitable as aggregate.

**28. (a)**
Amount of cement required for 1 $m^3$ of concrete = $x$ kg (say)

$$\therefore \quad x + 3x + 6x + 0.6x = 2500$$

$$\Rightarrow \quad x = 235.849 \text{ kg} \simeq 235.85 \text{ kg}$$

$$\text{Weight of water required} = 0.6 \times \text{Weight of cement}$$

$$= 141.51 \text{ kg}$$

$$\therefore \quad \text{Volume of water required, } V = \frac{141.51 \text{ kg}}{1000 \text{ kg/m}^3} = 141.51 \text{ litre} \simeq 141.5 \text{ lt}$$

**29.** (b)
- Sulphate attack causes formation of ettringite, an expansive compound that leads to internal stresses and cracking in mortar and concrete.
- Lime mortar primarily undergoes shrinkage during setting and carbonation, but does not exhibit significant volume change after these stages if properly cured. Volume changes afterward are minimal under normal conditions.
- Moisture variations (wetting and drying) have a greater impact on volume change (shrinkage and swelling) than temperature changes, especially in mortars and concrete.

**30. (b)**

Chrome-nickel stainless steel is not affected by acids. It is widely used for household utensils, vessels to store acids, dairy plant equipments, etc.

**31.** (a)

**32. (c)**

- $C_3S$ reacts rapidly with water, contributing to early hydration.
- The hydration of $C_3S$ is exothermic, leading to rapid heat generation (important in mass concrete).
- $C_3S$ is primarily responsible for early strength gain (within the first 7 days).

**33. (d)**

Fat lime has high degree of plasticity and sets slowly in presence of air.

**34. (c)**

Proportion of mix = 1 : 3 : 6

Assume volume of cement = 1 $m^3$

then, volume of sand = 3 $m^3$

Volume of aggregate = 6 $m^3$

$$\text{Actual volume of sand} = 3\left(1 + \frac{20}{100}\right) = 3.6 \text{ m}^3$$

**35. (b)**

Vehicle is a non-volatile fluid in which the solid body material is suspended and comprises 85%-90% drying oil plus 10%-15% drier and thinner. Examples of vehicle are:

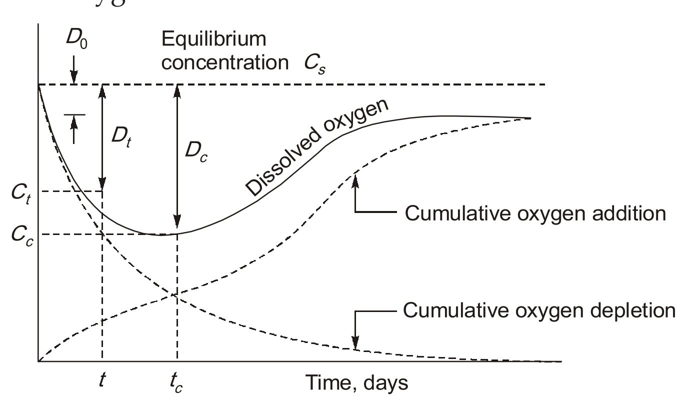
1. **Drying oil :** Linseed oil from flax seeds, fish oil, dehydrated castor oil, tung oil, perilla oil.
2. **Drier :** Organic salts of various metals such as PbO (litharge) for lead based paints and $ZnSO_4$ and MnO for zinc based paints.
3. **Thinner :** Volatile solvents like turpentine, petroleum fractions like naphtha, benzene.

**36. (b)**

Bulk density of light weight concrete varies from 300 to 1200 kg/$m^3$.

**37. (a)**

Oxygen sag curve results from deoxygenation and reoxygenation curve hence is a function of both addition and depletion of oxygen from the stream.



**38. (d)**

In the first stage of decomposition of organic matter in sewage, ammonia is formed.
The gas coming out from a sludge digestion tank is 70% methane and 30% carbon dioxide.

**39. (c)**

Detention period for a circular tank is

$$D = \frac{V}{Q}$$

where, Volume of tank, $V = D^2(0.01\,D + 0.785\,H)$

$D$ = Diameter of tank = 36 m

$H$ = Side water depth = 2.9 m

$Q$ = Half of the total discharge as two tanks are in operation = $\frac{36000}{2}$ = 18000 $m^3/d$

$$\therefore \quad t_D = \frac{36^2(0.011\times 36 + 0.785\times 2.9)}{18000}$$

= 0.1924 days = 4.618 hr

**40. (d)**

50 ml of 0.02 N $H_2SO_4$ is required to reduce the pH upto 4.5
Total alkalinity of 350 ml of water sample = 50 mg as $CaCO_3$

So, total alkalinity of water in mg/$l$ = $\frac{50\times 1000}{350}$ = 142.85 mg/$l$ as $CaCO_3$

**41. (d)**

Volume of Sewage, $V_s$ = 55 ml

DO of sewage, $DO_s$ = 0 mg/$l$

Volume of fresh water, $V_w$ = 200 – 55 = 145 ml

DO of fresh water, $DO_w$ = 15 mg/$l$

Dissolved oxygen of mixture:

$$(D.O.)_{mix} = \frac{DO_sV_s + DO_wV_w}{V_s + V_w}$$

$$\Rightarrow \quad (D.O.)_{mix} = \frac{0\times 55 + 15\times 145}{55 + 145} = 10.875 \text{ mg}/l$$

$BOD_s$ = (Initial DO-Final DO) x Dilution factor

$$= (10.875 - 3) \times \frac{200}{55} = 28.636 \text{ mg}/l$$

$\simeq$ 29 mg/$l$

**42. (b)**

Given data $\eta_1$ = 90% and $\eta_2$ = 95%

Since the efficiency of upstream ESP is 90% and thus only 10% of the particulate matter are not removed. These remaining particulate matter will face the downstream ESP whose efficiency is 95%.

$\therefore$ Particulate removed by downstream ESP = $\frac{10 \times 95}{100} = 9.5\%$

Two $ESP_S$ are in series, therefore the overall efficiency = 90 +9.5 = 99.5%

**Alternatively**:

$$1 - \eta_0 = (1 - \eta_1)(1 - \eta_2)$$

$$\Rightarrow \quad 1 - \eta_0 = (1 - 0.90)(1 - 0.95)$$

$$\Rightarrow \quad \eta_0 = 0.995 = 99.5\%$$

**43. (c)**

Drain valves are provided at low points for completely emptying a pipe after the supply has been closed.

**44. (c)**

- The efficiency of a sedimentation tank depends on laminar flow conditions. When cross currents, turbulence, or eddies are present, they disturb the settling of particles, reducing the removal efficiency. These disturbances prevent suspended solids from settling uniformly, thereby decreasing the performance of the tank.

The flow-through period (also known as actual detention time) is typically less than the theoretical detention period because:

- Not all water particles remain in the tank for the full theoretical time.
- Short-circuiting and dead zones reduce the effective contact time.
- Theoretical detention time is calculated assuming ideal plug flow, which doesn't occur in reality.

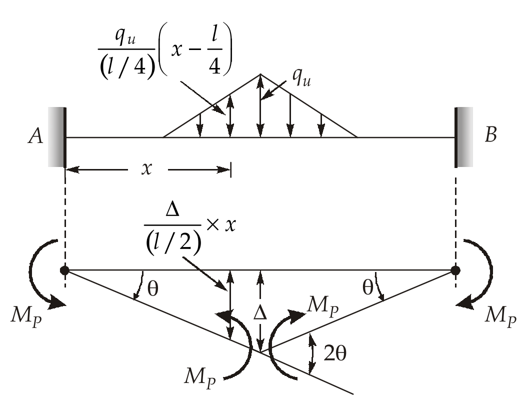
**45. (c)**

**46. (a)**

$$S_0 = 200 \text{ mg}/l = 0.2 \text{ kg/m}^3$$

$$\text{F/M} = \frac{Q_0 S_0}{VX} = \frac{0.2 \times 12000}{2500 \times 5} = 0.192$$

**47. (c)**



By principle of virtue work

$$W_e = W_i$$

$$\Rightarrow \quad 2\int_{l/4}^{l/2} \frac{q_u}{(l/4)}\left(x-\frac{l}{4}\right)dx\left(\frac{\Delta}{l/2}\right)x = M_p\theta + M_p \times 2\theta + M_p\theta$$

$$\Rightarrow \quad \frac{5}{24}q_u l\,\Delta = 4M_p\left(\frac{2\Delta}{l}\right)$$

$$q_u = \frac{192\,M_p}{5l^2}$$

**48. (c)**

$$\text{Throat thickness} = 0.7 \times \text{Size of weld}$$
$$= 0.7 \times 8 = 5.6 \text{ mm}$$

$$\text{Safe force} = \frac{(80\times 2+50)\times 5.6\times 100}{1000} = \frac{210\times 5.6\times 100}{1000} = 117.60 \text{ kN}$$

**49. (a)**

For limit state of serviceability

Partial safety factors for:

Dead load = 1.0

Live load = 1.0

Factored dead load = 1.0 × (6 + 1.5) = 7.5 kN/$m^2$

Factored live load = 1 × 5 = 5 kN/$m^2$

Design factored load for serviceability = 5 + 7.5 = 12.5 kN/$m^2$

**50. (b)**

Design flexural capacity of laterally unsupported beam is given by,

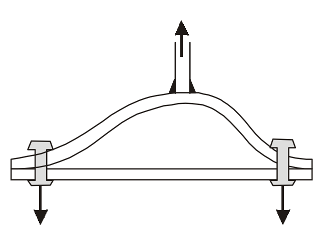
$$M_d = \beta_b z_p \frac{f_y}{\gamma_{m0}}$$

$$\beta_b = 1.0 \text{ (for plastic and compact section)}$$

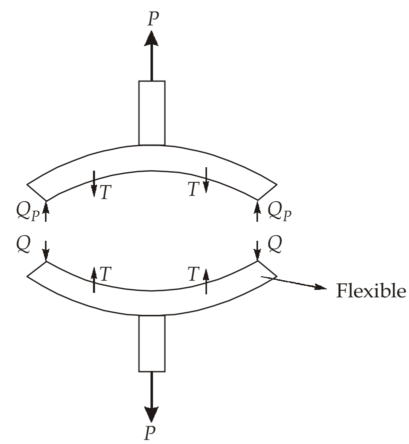
$$\therefore \quad M_d = 1.0 \times 600 \times 10^3 \times 200 \times 10^{-6}$$
$$= 120 \text{ kNm}$$

**51. (b)**

Prying forces are additional tensile forces due to flexibility of connected parts leading to deformations.



Free body diagram




$$2T = P + 2Q_P$$

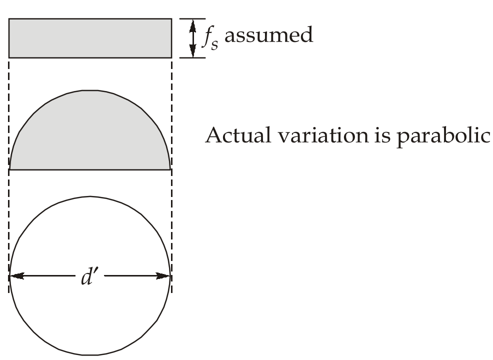
$\Rightarrow$ $$T = \frac{P}{2} + Q_P, \text{ where } Q_P \text{ is prying force}$$

Note : Due to prying force, force in bolt increases. The prying forces can be kept small by using a thick plate or by limiting the distance between the bolt and the plate edge.

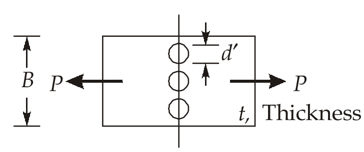
**52. (d)**

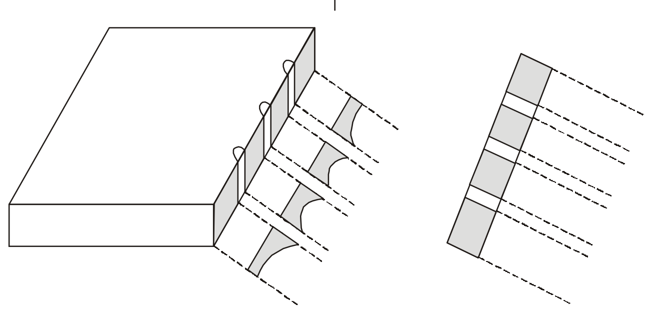
Bending stress in the rivet is neglected.

Shear stress over the cross-section of bolt is assumed to be constant



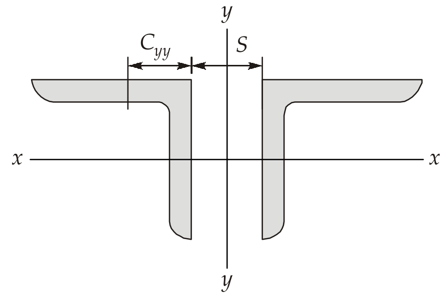

Distribution of direct stress on the portion of plate between the bolt holes is assumed to be constant.



Actual stress distribution Assumed stress distribution

**53. (c)**




$$I_{xx,\text{ combination}} = 2I_{xx,\text{ one}}$$

$$I_{yy,\text{ combination}} = 2\left[I_{yy,one} + A_{one}\left(C_{yy} + \frac{S}{2}\right)^2\right]$$

$\Rightarrow$ $$I_{min} = I_{yy,\text{ combination}}$$

($\because$ $I_{yy',\text{ combination}}$ governs minimum moment of inertia).

$\therefore$ $I_{min}$ increases as spacing increases.

$$r_{min}\text{ (radius of gyration)} = \sqrt{\frac{I_{min}}{A}}$$

$$\lambda\text{ (Slenderness ratio)} = \frac{l_{eff}}{r_{min}}$$

$\therefore$ More spacing implies more $I_{min}$ and thus more $r_{min}$ and thus lesser $\lambda$ and thus more is the design compressive stress ($\sigma_{ac}$). Thus more is the load carrying capacity.

**54. (c)**

$$\beta = 1.4 - 0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right)$$

But $$0.7 \le \beta \le \frac{0.9 f_u/\gamma_{m1}}{f_y/\gamma_{m0}}$$

$\Rightarrow$ $$0.7 \le \beta \le \frac{0.9\times 410/1.25}{250/1.1}$$

$\Rightarrow$ $$0.7 \le \beta \le 1.3$$

Hence maximum value of $\beta = 1.3$

**55. (a)**

All natural channels generally have varying cross-section and consequently are non prismatic. Spatially varied flow can be steady or unsteady.

**56. (a)**

$\because$ $$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dE}{dx}$$

$\Rightarrow$ $$-s_f = -s_0 + \frac{dE}{dx}$$

$$\Rightarrow \quad \frac{dE}{dx} = s_0 - s_f$$

$$\Rightarrow \quad \frac{dE}{dx} = 0.5 \times 10^{-5} - 1 \times 10^{-5} = -0.5 \times 10^{-5}$$

$$\text{Magnitude of } \frac{dE}{dx} = 0.5 \times 10^{-5}$$

**57. (c)**

**58. (b)**

Given, $E = 2$ N-m/N

For a rectangular channel we know that for a given specific energy the discharge is maximum when the flow is in critical state.

$$\therefore \quad y_c = \frac{2}{3}E_c = \frac{2}{3} \times 2 = \frac{4}{3} \text{ m} = 1.33 \text{ m}$$

Also,

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

$$\Rightarrow \quad y_c^3 = \frac{q^2}{g}$$

$$\Rightarrow \quad q^2 = (1.33)^3 \times 10 = 2.35 \times 10 = 23.5 \text{ m}^4/\text{s}^2$$

$$\Rightarrow \quad q = \sqrt{23.5} = 4.85 \text{ m}^2/\text{s}$$

Therefore,

$$Q = q \times b = 4.85 \times 2 = 9.7 \text{ m}^3/\text{s}$$

**59. (d)**

Using equation,

$$\frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$\Rightarrow \quad N_2 = \sqrt{H_2} \times \frac{N_1}{\sqrt{H_1}}$$

$$= \sqrt{\frac{H_2}{H_1}} \times N_1 = \sqrt{\frac{81}{100}} \times 200$$

$$= \frac{9}{10} \times 200 = 180 \text{ rpm}$$

**60. (b)**

Buoyant force acts through center of gravity of displaced liquid.

A large metacentric height in a vessel improves stability and makes time period of oscillation shorter.

**61. (a)**

$$\text{Time period of oscillation, } T = 2\pi\sqrt{\frac{K^2}{g\cdot(GM)}}$$

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{9\times 9}{10\times 0.9}} = 2\pi\times\frac{9}{3} = 6\pi$$

**62. (c)**

From figure, the value of $\bar{x}$ may be determined as follows:

$$\angle AOP = 10°$$

$$OP = AO\cos 10°$$

$$AO = \left(\frac{1}{\sqrt{2}}\cos 10°\right) = 0.696 \text{ m}$$

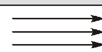
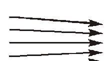
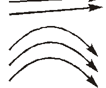
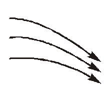
$$\bar{x} = (1.5 + 0.696)$$

$$P = \rho g A\bar{h}$$

$$= 1000 \times 9.81 \times 1 \times 2.196$$

$$= 21.5 \text{ kN}$$

**63. (c)**

| S.No. | Streamline pattern | | Type of acceleration |
|---|---|---|---|
| 1. | Straight parallel stream lines |  | No acceleration |
| 2. | Straight converging streamlines |  | Convective tangential acceleration |
| 3. | Concentric streamlines |  | Convective normal acceleration |
| 4. | Curved converging streamlines |  | Both tangential and normal convective acceleration |

**64. (c)**

The change in shear rate is constant with respect to proportional increment in shear stress. Also shear stress is zero when shear rate is equal to zero. Thus the fluid is Newtonion

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

At $\quad \frac{du}{dy} = 0, \tau = 0$

$\Rightarrow \quad B = 0$

Also, $\quad n = 1$

$\Rightarrow$ Fluid is Newtonian.

**65. (c)**

According to Newton's law of viscosity,

$$\tau = \mu \frac{du}{dy}$$

$$\text{Velocity profile, } u = \frac{3}{4}y - y^2$$

$$\text{Dynamic viscosity, } \mu = 0.84 \text{ Ns/m}^2$$

Differentiating '$u$' w.r.t. '$y$',

$$\frac{du}{dy} = \frac{3}{4} - 2y$$

At $y = 0.3$ m, $$\frac{du}{dy} = \frac{3}{4} - 2 \times 0.3 = 0.15 \text{ m/s/m}$$

At $y = 0.2$ m, $$\frac{du}{dy} = \frac{3}{4} - 2 \times 0.2 = 0.35 \text{ m/s/m}$$

Given $$(\tau)_{0.3\text{ m}} = N(\tau)_{0.2\text{ m}}$$

$\Rightarrow$ $$0.15 = N(0.35)$$

$\Rightarrow$ $$N = \frac{15}{35} = \left(\frac{3}{7}\right)$$

**66. (b)**

As per Bernoulli's equation total head,

$$H = \frac{p}{\rho g} + Z + \frac{V^2}{2g}$$

Where,

$\frac{p}{\rho g}$ is pressure head or static head

$Z$ is datum or elevation head

$\frac{V^2}{2g}$ is velocity head or dynamic head or kinetic head

$\frac{p}{\rho g} + Z$ is also called piezometric head

$\frac{p}{\rho g} + \frac{V^2}{2g}$ is called stagnation head

and $\frac{p}{\rho g} + Z + \frac{V^2}{2g} =$ Total head

**67. (a)**

In a two-dimensional boundary layer over a flat surface:

- **Longitudinal (streamwise) pressure gradient:** This affects the velocity distribution within the boundary layer and is significant in determining the flow behavior (e.g., whether it accelerates or decelerates).
- **Transverse (normal to the surface) pressure gradient:** This is very small and typically negligible because the boundary layer is thin and the pressure is considered constant in the direction normal to the wall.

**68. (b)**

$$CBR_{@2.5\ mm} = \frac{54.8}{1370} \times 100 = 4\%$$

$$CBR_{@5\ mm} = \frac{61.65}{2055} \times 100 = 3\%$$

So, $CBR = 4\%$

**69. (c)**

$\because \quad q = Uk$

$\Rightarrow \quad q = 60k - 0.45k^2$

For $q$ to be maximum $\frac{dq}{dk} = 0$, and $\frac{d^2q}{dk^2} < 0$

$$\Rightarrow \quad \frac{dq}{dk} = 60 - 0.45 \times 2k = 0 \quad \text{and} \quad \frac{d^2q}{dk^2} = -0.9 < 0 \quad \text{(O.K.)}$$

$$\Rightarrow \quad k = \frac{200}{3}$$

$$\therefore \quad q_{max} = 60 \times \frac{200}{3} - 0.45 \times \left(\frac{200}{3}\right)^2 = 2000 \text{ vph}$$

**70. (c)**

Regulatory signs are also known as mandatory signs.

**71. (d)**

$$\text{Percentage tractive force resisted} = \frac{T(1-\cos\alpha)}{T} \times 100$$

$$= (1 - \cos\alpha) \times 100$$

$$= (1 - \cos 60°) \times 100 = 50\%$$

**72. (b)**

Angle parking accommodates more vehicles per unit length of kerb and maximum vehicles can be parked when angle is 90°.

**73. (c)**

**74. (b)**

| Flat footed rails | Bull headed rails |
|---|---|
| More strength and stiff | Less strength and stiffness for same weight |
| Fastenings are lesser and cheaper | Fastenings are more and costly so initial cost is high |
| Less maintenance cost | More maintenance cost |

**75. (b)**

We know that,

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

$$L = 9 \text{ sec}$$

$$Y = \frac{800}{2000} + \frac{900}{3000} = 0.7$$

$$C_0 = \frac{1.5 \times 9 + 5}{1 - 0.7} = 61.67 \simeq 62 \text{ sec}$$

**76. (b)**

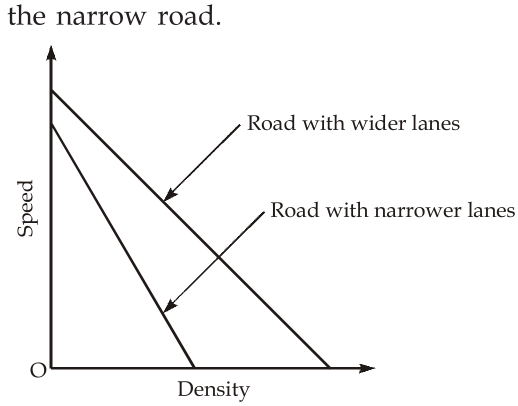
When the prevailing traffic condition is so bad that due to traffic congestion, the traffic may come to a stand-still condition and in such a situation, the possible capacity of the road may approach zero.

When the prevailing roadway and traffic conditions approach the ideal conditions, the possible capacity also approach the basic capacity. Thus the value of possible capacity varies from zero to basic capacity. For the purpose of design, neither basic capacity nor possible capacity can be adopted as they represent two extreme cases of roadway and traffic conditions.

**77. (a)**

**78. (b)**

Both free flow speed and jam density will be lesser in the case of the narrow lane width road than in the case for a wide lane width road. Further the speed at any given density is expected to be lower on the narrow road. This is because individual drivers will drive at a lesser speed at a given distance headway than they would have done on the wider road possibly due to a higher perception of threat to one's safety on the narrow road.



**79. (b)**

$$q_u = cN_c + qN_q + 0.5B\gamma N_\gamma \quad (\because \text{For normally consolidated clay, } c = 0)$$
$$= 1 \times 16 \times 60 + 0.5 \times 16 \times 1.5 \times 75$$
$$= 1860 \text{ kN/m}^2$$

**80. (d)**

Rankine's theory over estimates the active earth pressure and underestimates the passive earth pressure.

**81. (b)**

$$\because \quad H_c = \frac{4c}{\gamma\sqrt{k_a}}$$

$$k_a = \frac{1 - \sin 0°}{1 + \sin 0°} = 1 \qquad \{\because \text{ For clay } \phi = 0°\}$$

$$\therefore \quad H_c = \frac{4 \times 20}{18} = 4.44 \text{ m} \simeq 4.4 \text{ m}$$

**82. (d)**

Specific gravity of soil = 2.74

Mass of soil = 133.7 gm

Volume of suspension = 1000 cc

$$\therefore \quad \text{Volume of soil} = \frac{\text{Mass of soil}}{\text{Density of soil } (\rho_s)} \qquad [\because \rho_s = \rho_w \cdot G]$$

$$= \frac{133.7}{1 \times 2.74} \text{ cc} = 48.796 \text{ cc} \simeq 48.8 \text{ cc}$$

Volume of water in 1000 m*l* of suspension

$$= 1000 - 48.8 = 951.2 \text{ cc}$$

Mass of water in 1000 m*l* of suspension = 951.2 g

Total mass of suspension = 133.7 + 951.2 = 1084.9 g

$$\therefore \quad \text{Density of suspension} = \frac{1084.9}{1000} \text{ g/cc} = 1084.9 \text{ kg/m}^3$$

**83. (d)**

Quick clay is a type of clay and has sensitivity > 30. It loses its strength significantly when disturbed.

**84. (c)**

Reinforcement in soil interacts with the soil through friction, adhesion or passive/bearing resistance. Whereas reinforcement in concrete interacts with concrete through cementitious bond.

**85. (b)**

$$n = 0.5; \quad \therefore \quad e = \frac{n}{1-n} = \frac{0.5}{0.5} = 1$$

$$\because \quad Se = wG$$

$S = 0.7;\ e = 1;\ G = 2.7$

$$\therefore \quad w = \frac{Se}{G} = \frac{0.7 \times 1}{2.7} = 0.259$$

$$\therefore \quad \gamma = \frac{(G + Se)\gamma_w}{1+e} = \frac{G\gamma_w(1+w)}{1+e} = \frac{2.7 \times 10 \times 1.259}{2}$$

$$= 16.99 \text{ kN/m}^3$$

**86. (a)**

**87. (d)**

We know that,

$$T_V = C_V \frac{t}{d^2}$$

$$\therefore \quad \frac{t}{d^2} = \frac{T_V}{C_V}$$

As in both the cases, the soil is same, therefore $C_V$ will be constant.
Also, there is same degree of consolidation i.e. 40% in both cases, hence $T_V$ will be constant

$$\text{i.e.} \quad T_V = \frac{\pi}{4}U^2 \text{ if } U < 0.6$$

$$\Rightarrow \quad \frac{t}{d^2} = \frac{T_V}{C_V} = \text{Constant}$$

$$\Rightarrow \quad \frac{t_1}{d_1^2} = \frac{t_2}{d_2^2}$$

$$\Rightarrow \quad \frac{12}{\left(\frac{2}{2}\right)^2} = \frac{t_2}{\left(\frac{600}{2}\right)^2}$$

$$\Rightarrow \quad t_2 = 12 \times \left(\frac{600}{2}\right)^2 = 12 \times (300)^2 \text{ minute}$$

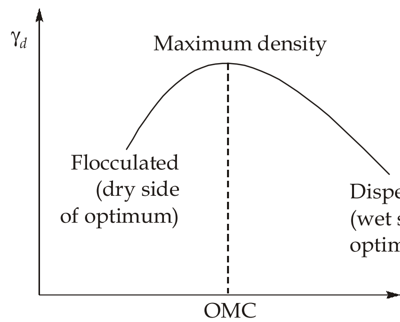
$$\Rightarrow \quad t_2 = \frac{12 \times (300)^2}{60 \times 24} \text{ days}$$

$$\Rightarrow \quad t_2 = \frac{12 \times 300 \times 5}{24} = 150 \times 5 = 750 \text{ days}$$

**88. (b)**

$$\text{Shrinkage ratio} = \frac{\gamma_d}{\gamma_\omega} = \frac{20/15}{1} = \frac{4}{3}$$

**89. (a)**




**90. (b)**

Canal drop or fall is provided whenever the available natural ground slope is steeper than the designed bed slope of the channel. Thus it controls the grade of bed.

Canal escape is constructed as a side channel to remove surplus water from an irrigation channel into a natural drain. The water in the irrigation channel may become surplus due to some mistake, or difficulty in regulation at the head, or due to excessive rainfall in upper reaches. Thus it controls the full supply level to avoid breaching of canal and works as a safety valve. The minimum capacity of the escape is generally kept half of the channel capacity at the point of escape.

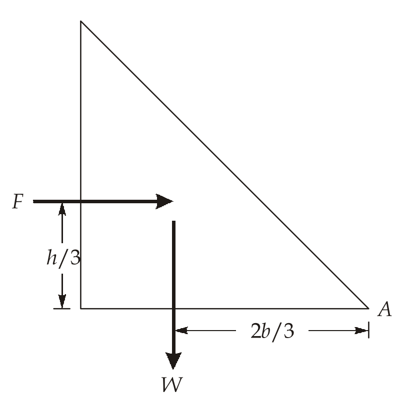
Canal cross-regulator controls the flow depth by heading up water on the upstream side when the water level in main channel is low.

Canal outlets or modules are built at the head of the water course so as to connect it with a minor or distributary channel. Canal outlets control discharge to watercourse on the principle of equitable distribution of water.

**91. (b)**

$$V = 0.55\, m y^{0.64}$$
$$= 0.55 \times 1.1 \times (1)^{0.64}$$
$$= 0.605 \text{ m/s}$$

**92. (d)**




In limiting condition,

$$\Sigma M_A = 0$$

$$\Rightarrow \quad F \times \frac{h}{3} = W \times \frac{2b}{3}$$

$$\Rightarrow \quad \frac{\gamma_w h^2}{2} \cdot \frac{h}{3} = \frac{bh}{2}(2.56\gamma_w)\frac{2b}{3}$$

$$\Rightarrow \quad b^2 = 0.1953h^2$$

$$\Rightarrow \quad b = 0.44h$$

**93. (c)**

$$\alpha = \frac{b}{d} = \frac{10}{4} = 2.5$$

$$\therefore \quad \lambda = \frac{1+\sqrt{1+\alpha^2}}{2} = \frac{1+\sqrt{1+2.5^2}}{2} = 1.85$$

$$\therefore \quad \text{Exit gradient, } G_E = \frac{H}{d} \times \frac{1}{\pi\sqrt{\lambda}} = \frac{5}{4} \times \frac{1}{\pi\sqrt{1.85}} = \frac{1}{3.4}$$

**94. (b)**

Groynes are embankment type structures, constructed transverse to the river flow, extending from the bank into the river. They are constructed to protect the bank from which they are extended, by deflecting the current away from the bank. These are called repelling groynes. On the upstream side of a repelling groyne, a still water pocket is formed, where the suspended sediments carried by the river, gets deposited. For low water training or training for depth, groynes can be used. Here they contract the width of the channel to provide sufficient depth for navigation during low water periods.

In order to train the flow along a certain course, guide banks are most commonly used. However groynes can also be used to deflect the flow or to attract the flow.

**95. (d)**

$$\text{Duty, } D = \frac{8.64B}{\Delta}$$

$$= \frac{8.64 \times 150}{0.2592} = 5000 \text{ ha/cumec}$$

$$\therefore \quad \text{Minimum discharge required} = \frac{100000}{5000} = 20 \text{ cumecs}$$

The distributary channel should be designed for a discharge more than 20 cumecs.

**96. (a)**

$$Q = 3600 \text{ m}^3/\text{s}$$

$$\text{Waterway} = L = 4.75\sqrt{Q} = 4.75\sqrt{3600} = 285 \text{ m}$$

**97. (c)**

- Drip irrigation delivers water directly to the root zone of plants in small, controlled amounts. This minimizes or eliminates deep percolation (water going too deep beyond root zone) and runoff (water flowing away without being absorbed).
- Drip irrigation has one of the highest water application efficiencies (up to 90–95%) because it minimizes evaporation, runoff, and percolation losses.
- Drip systems are ideal for applying fertilizers directly to the root zone, making it efficient and cost-effective.

**98. (c)**

**99. (d)**

Net irrigation requirement = Consumptive use – Effective Rainfall

$$\text{Consumptive use} = 0.5 \times (0.2 - 0.1) \times \frac{15}{10} \times 1000$$

$$= 0.05 \times \frac{15}{10} \times 1000 = 75 \text{ mm}$$

Effective rainfall = 50 mm

∴ Net irrigation requirement = 75 mm – 50 mm = 25 mm

**100. (c)**

Optimum number of raingauge stations (N) is given by

$$N = \left(\frac{C_V}{E}\right)^2$$

where $C_V$ = Coefficient of variation = 40%

$E$ = Admissible error = 10%

$$N = \left(\frac{40}{10}\right)^2 = 16$$

$$\Rightarrow \quad N \simeq 16$$

**101. (c)**

The intensity of rain is nearly inversely proportional to the duration of the rain.

$$P = \frac{a}{T+b}$$

where $P$ = Rainfall intensity in cm/hr

$T$ = Time in minutes

$a$ and $b$ = constants

**102. (a)**

The equation used for the determination of PMP is

$$\text{PMP} = \bar{P} + k\sigma$$

**103. (b)**

**104. (b)**

Consumptive Irrigation Requirement,

$$CIR = C_u - R_e$$

$C_u$ is Consumptive use of crop

$R_e$ is Effective rainfall

Net Irrigation Requirement, NIR = CIR + Water lost as percolation in satisfying other needs such as leaching.

$$\text{Field Irrigation Requirement, FIR} = \frac{NIR}{\text{Water application efficiency } (\eta_a)}$$

Thus,

FIR = NIR + Percolation losses in field watercourses and field channels

$$\text{Gross Irrigation Requirement, GIR} = \frac{FIR}{\text{Efficiency of Water Conveyance } (\eta_c)}$$

∴ GIR = FIR + Conveyance losses in distributaries upto the field.

So, GIR > FIR > NIR > CIR

**105. (a)**

$$\frac{1}{2} \times 144 \times Q \times 60 \times 60 = 596 \times 10^6 \times \frac{1}{100}$$

$$\Rightarrow \quad 25.92 \times 10^4 Q = 596 \times 10^4$$

$$\Rightarrow \quad Q = 22.99 \simeq 23 \text{ m}^3/\text{s}$$

**106. (c)**

$$l \cos\theta = -60 \text{ m}$$

$$l \sin\theta = 103.92 \text{ m}$$

$$\therefore \quad \tan\theta = -1.732 = -\sqrt{3}$$

$$\Rightarrow \quad \theta = -60°$$

As latitude is –ve and departure is +ve, therefore line *AB* lies in second quadrant.

$$\therefore \quad \text{WCB of } AB = 180° - 60° = 120°$$

**107. (c)**

$$\text{Shrinkage factor} = \frac{\text{Shrunk scale}}{\text{Original scale}} = \frac{14.5}{15}$$

$$\text{Shrunk } RF = \text{Original } RF \times \text{Shrinkage factor}$$

$$= \frac{1}{1000} \times \frac{14.5}{15} = \frac{1}{1034.48}$$

$$\therefore \quad \text{Shrunk scale, 1 cm} = \frac{1034.48}{100} = 10.34 \text{ m}$$

**108. (a)**

**109. (d)**

$$\text{First RL} = 51.45 \text{ m, Last RL} = 63.50 \text{ m}$$
$$\Sigma BS = 87.755 \text{ m}, \Sigma FS = 73.725 \text{ m}$$

When there is no error, then

$$\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL} \quad \text{...(i)}$$

The difference between LHS and RHS is the closing error of the work.

$$\text{LHS} = \Sigma BS - \Sigma FS = 87.755 - 73.725 = 14.03 \text{ m}$$
$$\text{LHS} = \text{Last RL} - \text{First RL} = 63.50 - 51.45 = 12.05 \text{ m}$$
$$\therefore \quad \text{Closing error} = 14.03 - 12.05 = 1.98 \text{ m}$$

**110. (c)**

**111.** (b)

In certain electro-magnetic EDM instruments, intervisivility of stations is not required.

**112. (b)**

Surveyor's compass has an edge bar needle while prismatic compass has broad needle.

**113. (a)**

Given, elevation of tower from the bottom is 1250 m.

$$\therefore \quad d = \frac{hr}{H}$$

Here,

$$h = 50 \text{ m}$$
$$H = 2500 - 1250 = 1250 \text{ m}$$
$$\therefore \quad d = \frac{50 \times 6.35}{1250} = 0.254 \text{ cm} \simeq 0.25 \text{ cm}$$

**114. (a)**

For M20, ITR ≥ ($f_{ck}$ – 4) N/mm$^2$

**115. (a)**

Let section is under-reinforced so that $f_{st} = 0.87 f_y$

$$\therefore \quad 0.36 \times 20 \times 300 \times x_u = 0.87 \times f_y \times 4 \times \frac{\pi}{4} \times 16^2 \qquad \left(f_y = 500 \text{ N/mm}^2\right)$$

On solving, $x_u \simeq 162$ mm

$$\text{For Fe500, } x_{u,\,\text{lim}} = 0.46 \times 450 = 207 \text{ mm}$$

$\therefore \quad x_u < x_{u,\,\text{lim}} \Rightarrow$ Under-reinforced section and assumption is correct.

$$\therefore \quad \text{Lever arm } (z) = d - 0.42\, x_u$$
$$= 450 - 0.42 \times 162 = 381.96 \simeq 382 \text{ mm}$$

**116. (c)**

Singly reinforced beam is more economical than doubly reinforced beam.

**117.** (d)

**118.** (d)

**119. (a)**

$$\text{Resultant load} = 26 + 19 = 45 \text{ kN/m}$$

$$\text{Resultant moment} = 26 \times 0 + 19 \times 45$$

$$= 855 \text{ kN-mm/m}$$

$$\text{Resulting eccentricity, } e = \frac{855}{45} = 19 \text{ mm}$$

$$\text{Eccentricity ratio} = \frac{e}{t} = \frac{19}{200} = 0.095$$

Eccentricity ratio can have maximum value of 0.50.

**120. (a)**

$$\text{Area of footing} = 2 \times 3 = 6 \text{ m}^2$$

$$\text{Section modulus about } x\text{-}x \text{ axis, } Z = \frac{b \times d^2}{6} = \frac{2 \times 3^2}{6} = 3\,\text{m}^3$$

$$\text{Stress, } \sigma = \frac{P}{A} \pm \frac{M}{Z}$$

$$\therefore \quad 95 = \frac{P}{A} + \frac{M}{Z} \quad \ldots(i)$$

$$\text{and,} \quad 55 = \frac{P}{A} - \frac{M}{Z} \quad \ldots(ii)$$

From (*i*) and (*ii*), we get

$$40 = 2 \times \frac{M}{Z}$$

$$\Rightarrow \quad 40 = 2 \times \frac{M}{3}$$

$$\Rightarrow \quad M = 60 \text{ kNm}$$

**121. (a)**

$$\text{Strain due to shrinkage} = \frac{2 \times 10^{-4}}{\log_{10}(t+2)} = 2 \times 10^{-4} \quad (\because \; t = 8 \text{ days})$$

$$\therefore \quad \text{Loss of prestress, } \Delta\sigma = 2 \times 10^{-4} \times E_s$$

$$= 2 \times 10^{-4} \times 2 \times 10^5 = 40 \text{ N/mm}^2$$

$$\therefore \quad \text{Percentage of prestress loss} = \frac{40 \times 100}{500} = 8\%$$

**122. (d)**

**123. (d)**

Mode of failure (compression or tension) depends on relative magnitude of $M_u$ and $P_u$.

If $\frac{M_u}{P_u}$ is small, then $P_u$ is predominant

$\therefore$ Failure is compressive.

If $\frac{M_u}{P_u}$ is large, then $M_u$ is predominant

$\therefore$ Failure is due to flexure.

**124. (d)**

$$\frac{A_{sv\,\min}}{S_v} = \frac{0.4B}{0.87 f_y}$$

$$\Rightarrow \quad \frac{2 \times \frac{\pi}{4} \times 8^2}{S_v} = \frac{0.4 \times 230}{0.87 \times 415}$$

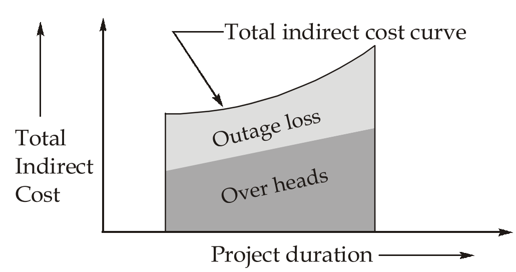
$$\therefore \quad S_v = 394.5 \text{ mm} > 300 \text{ mm}$$

Spacing of shear reinforcement should not be greater than 300 mm and thus required spacing of shear reinforcement is 300 mm.

**125. (b)**

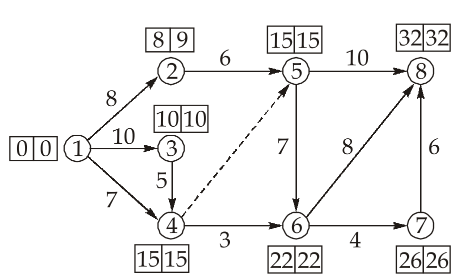
Statements 1 and 3 are wrong. The crash estimate involves the absolute minimum time required for the job and the cost necessary to achieve it. Here the emphasis is on time.

If outage losses are also included in the project cost, the curve for indirect cost will be as shown




**126. (c)**

EST and LST (Event times) for each event are indicated on the CPM network diagram.




So, the project duration is 32 days.

**127. (a)**

$$Z \text{ corresponding to 95\% probability} = 1.647$$
$$T_E = 60 \text{ weeks}$$
$$\sigma = \sqrt{\sigma^2} = \sqrt{9} = 3 \text{ weeks}$$
$$\therefore \quad Z = \frac{T_S - T_E}{\sigma}$$
$$\Rightarrow \quad 1.647 = \frac{T_S - 60}{3}$$
$$\Rightarrow \quad T_S = 60 + 3 \times 1.647$$
$$= 64.941 \text{ weeks} \simeq 65 \text{ weeks}$$

**128. (c)**

**129. (b)**

**130. (d)**

**131. (c)**

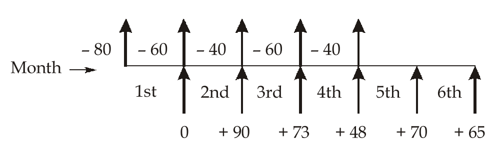
Activity $C$ cannot start before completion of activity $A$. Similarly activity $E$ cannot start before completion of activity $C$. Thus, $A$, $C$ and $E$ are critical activities.

**132. (a)**

$$Z = \frac{T_S - T_E}{\sigma} \qquad \left[\sigma^2 = 12, \sigma = 3.46\right]$$
$$= \frac{50 - 47}{3.46} \qquad [T_E = 6 + 8 + 18 + 8 + 7 = 47 \text{ days}]$$
$$= 0.867$$

**133. (c)**

Cash flow diagram




Outflows are shown negative and inflows as positive

After four months, net cash flow

$$= 90 + 73 + 48 - 80 - 60 - 40 - 60 - 40$$
$$= -69 \text{ money units}$$

**134. (d)**

**135. (a)**

**136. (c)**

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

**137. (d)**

Column analogy method is force method of analysis.

**138. (c)**

- Fine cement has a greater surface area, leading to faster hydration and higher water demand. This results in increased shrinkage and a greater risk of shrinkage cracks during drying.
- The fineness of cement affects setting time. Fine cement sets faster than coarse cement because its increased surface area accelerates the hydration process.

**139. (d)**

- The field capacity of municipal solid waste refers to the maximum amount of moisture that can be retained in the waste material against the force of gravity, not surface tension. Any moisture beyond this capacity becomes leachate and drains out under gravitational force.
- The field capacity is indeed crucial in landfill design, as it directly influences how much water can be retained in the waste. If the water content exceeds the field capacity, the excess water becomes leachate, which must be carefully managed to avoid groundwater contamination.

**140. (a)**

**141. (c)**

If a circular chamber is introduced between the casing and the impeller, the casing is known as vortex casing. By introducing the circular chamber, the loss of energy due to formation of eddies is reduced to a considerable extent. Thus, the efficiency of the pump is more than the efficiency when only volute casing is provided.

**142. (b)**

Statement I states that for two dimensional, steady, uniform flow,

$$\frac{\partial p}{\partial x} = \frac{\partial \tau}{\partial y}$$

**143. (b)**

**144. (b)**

In direct shear stress test, drainage can not be controlled hence rate of loading should be such that pore water pressure does not develop i.e. it will be a drained condition testing.

**145. (d)**

**146. (a)**

Drip irrigation, also known as trickle irrigation, is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone.

Fertilizer and nutrient loss is minimized due to localized application and reduced leaching. Soil erosion and weed growth get reduced.

**147. (d)**

**148. (a)**

**149. (a)**

In column it is desirable that if it fails then it is due to failure in material and for this the maximum unsupported length is 60 times the least lateral dimension (b). as per Clause 25.3 of **IS 456:2000**. Further for cantilever column it should not exceed $\frac{100b^2}{D}$.

**150. (c)**

Controlling phase is undertaken during actual project operations.

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