DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 16

Section A : Transportation Engineering + Building Materials [All Topics]

Section B : Flow of Fluids, Hydraulic Machines and Hydro Power [All Topics]

Section C : Design of concrete and Masonry Structures - II [Part Syllabus]

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

DETAILED EXPLANATIONS

1. (d)

Length of state highway = 62.5 × Number of towns above 5000 population – $\frac{\text{Area}\left(\text{in km}^2\right)}{50}$

$$= 62.5 \times 661 - \frac{405000}{50}$$

$$= 33212.5 \simeq 33212 \text{ km}$$

2. (a)

$$\text{S.S.D.} = 0.278 \times V \times t_R + \frac{V^2}{254(f - n\%)}$$

Where

V = ruling design speed for N.H = 100 kmph

t_R = reaction time = 2.5 sec

f = 0.35 for V > 80 kmph

n = 2%

$$\therefore \quad \text{S.S.D} = 0.278 \times 100 \times 2.5 + \frac{100^2}{254(0.35 - 0.02)}$$

$$= 69.5 + 119.3 = 188.8 \text{ m}$$

3. (c)

Ruling design speed = 100 kmph

Minium design speed = 80 kmph

As per IRC, e = 0.07

f = 0.15

$$\text{Ruling minimum radius} = \frac{V^2}{127(e + f)} = \frac{(100)^2}{127 \times (0.07 + 0.15)} = 357.9 \text{ m}$$

$$\text{Absolute minimum radius} = \frac{(80)^2}{127 \times (0.07 + 0.15)} = 229.1 \text{ m}$$

5. (d)

$$q_{\max} = \frac{1}{4} \times V_f \times k_j$$

$$\Rightarrow \quad 2077 = \frac{1}{4} \times 42.76 \times k_j$$

$$\Rightarrow \quad k_j = 194.29 \text{ veh/km}$$

As the traffic density is half of jam density at capacity flow

$$\therefore \quad \text{Space headway} = \frac{1000}{(k_j/2)} \text{m} = \frac{2000}{194.29} = 10.29 \text{ m}$$

6. (c)

$$\text{Amber time} = \frac{\text{Length of intersection} + \text{length of vehicle} + SSt}{V}$$

If movement is straight and turning both, then four phase signal is provided.

7. (a)

$$(\text{PCU})_t = \frac{\text{Speed ratio}}{\text{Length ratio}} = \frac{V_0 / V_t}{L_0 / L_t} = \frac{(90/45)}{(5/10)} = 4$$

8. (b)

$$P(x = n) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$$

here, $\lambda = 360 \text{ veh}/3600 \text{ sec} = 0.1 \text{ veh/sec.}$

$t = 20 \text{ sec.}$

$$P(x \geq n) = 1 - [P(0) + P(1)]$$

$$P(0) = \frac{(0.1\times 20)^0 \times e^{-(0.1\times 20)}}{0!} = 0.135$$

$$P(1) = \frac{(0.1\times 20)^1 \times e^{-(0.1\times 20)}}{1!} = 0.270$$

$\therefore$ $$P(n \geq 2) = 1 - [0.135 + 0.27] = 0.595$$

9. (a)

Voids in mineral aggregates, $VMA = V_V\% + V_b\%$

Here $$V_V(\text{percent of air voids}) = \left(\frac{G_t - G_m}{G_t}\right)\times 100$$

$$= \frac{2.406 - 2.316}{2.406}\times 100 = 3.74\%$$

$$V_b(\text{percent volume of bitumen}) = \frac{\left(\frac{W_b}{G_b}\right)\times 100}{\left(\frac{W_{\text{total}}}{G_m}\right)}$$

$$= \frac{\left(\frac{100}{1.05}\right)}{\left(\frac{2600}{2.316}\right)}\times 100 = 8.48\%$$

$\therefore$ $$VMA = 3.74\% + 8.48\% = 12.22\%$$

10. (b)

Using rigid plate in Burmister formula,

$$\text{Deflection, } \Delta = 1.18 \times \frac{pa}{E_s} F_2$$

$$\Rightarrow \quad 0.5 = 1.18 \times \frac{5 \times 15}{E_s} \times 0.2$$

$$\Rightarrow \quad E_s = 35.4 \text{ kg/cm}^2$$

11. (a)

In surface dressing rolling is done with tandem roller of 6 to 8 tonnes weight.

For premix carpet carpet rolling is done by tandem or penumatic roller of 6 to 9 tonnes. In bituminous concrete and bituminous macadam initial or breaddown rolling shall be done with 8 to 10 tonnes dead weight smooth wheeled rollers. The intermediate rolling shall be done with 8 to 10 tonnes dead weight or vibratory roller or with a pneumatic tyred roller of 12 – 15 tonnes weight having nine wheels, with a tyre pressure of at least 5.6 kg/cm^2. The finish rolling shall be done with 6-8 tonnes smooth wheelded tandem rollers.

12. (c)

- Streaking is characterized by the appearance of lean and heavy lines of bitumen either in longitudinal or in transverse direction. It is a surface defect.
- Shoving is a form of plastic movement within the layer resulting in localized bulging of the pavement surface. It is a kind of deformation from original shape.

14. (a)

The force required to prevent the expansion due to temperature,

$$F = \alpha\, \Delta T \times A \times E$$
$$= 1.25 \times 10^{-5} \times 30° \times 60 \times 21 \times 10^5$$
$$= 47250 \text{ kg}$$

Length of track required to overcome temperature stress,

$$L_t = \frac{47250}{700} = 67.5 \text{ km}$$

To prevent creep for equilibrium, length of welded track is,

$$L = 2 \times L_t$$
$$= 2 \times 67.5 = 135 \text{ km}$$

15. (c)

Theoretical cant for main line = 7.972 cm

Maximum cant deficiency for B.G. = 7.5 cm

Actual cant for main track = 7.972 – 7.5

= 0.472 cm

Branch line:

Negative cant for branch line = – 0.472 cm

Theoretical cant for branch line = $e_{th} - 7.5$

$\Rightarrow \quad -0.472 = e_{th} - 7.5$

$\Rightarrow \quad e_{th} = 7.028 \text{ cm}$

19. (a)

- Standard temperature at airport is 15°C.
- No wind is blowing on runway.

20. (d)

Airport reference temperature, A.R.T. $= T_a + \dfrac{T_m - T_a}{3}$

$$= 26.32 + \frac{43.72 - 26.32}{3} = 32.12°\text{C}$$

Standard atmospheric temperature $= 15°\text{C} - 0.0065 \times 400 = 12.4°\text{C}$

$\therefore \quad \Delta T = 32.12° - 12.4°$

$= 19.72°\text{C}$

21. (c)

Maximum transverse gradient for type C airports is 1.5%.

24. (b)

The unsoundness of cement may be reduced by limiting the MgO content to 5 to 6 percent.

27. (b)

When water is added to the cement, the quickest to react with water is C_3A and in order of decreasing rate are C_4AF, C_3S and C_2S.

28. (c)

The total loss on ignition should not be greater than 5 percent as per table 2 of IS : 269 – 2013.

29. (b)

Let proportion of fine aggregate is x and that of coarse aggregate is $(1 - x)$.

Hence, $\quad (x)(2.5) + (1 - x)(6.5) = (1)(5.5)$

$\Rightarrow \quad x = 0.25$

i.e. $\quad x = 25\%$

$\therefore$ Thus the percentage of fine aggregate is 25%.

30. (b)

- Tensile strength of timber is 2 to 4 times greater than compressive strength parallel to grains.
- In deciduous tree, medullary rays are distinct and annual rings are indistinct.
- In conifer tree, medullary rays are indistinct and annual rings are distinct.

31. (c)

Wane is a defect in timber due to conversion, not due to seasoning.

33. (b)

The gel space ratio, x is given as

$$x = \frac{0.657c\alpha}{0.319c\alpha + W}$$

where, c is the weight of cement in gm, c = 400g
α is percentage hydration, α = 1
W is the volume of mixing water in ml

$$\therefore \quad \frac{W}{c} = 0.5 \Rightarrow W = 0.5 \times 400 = 200 \text{ ml}$$

Now,
$$x = \frac{0.657 \times 400 \times 1}{0.319 \times 400 \times 1 + 200} = 0.802$$

36. (c)

The light-weight concrete has generally a lower thermal expansion than ordinary concrete.

37. (c)

Glass gets affected by alkalies.

39. (a)

Concrete of desired strength can be achieved by weight batching method.

40. (d)

$$\text{Slot length of gauge} = 1.8 \times (\text{Mean size of aggregate})$$
$$= 1.8 \times \left(\frac{50+60}{2}\right) = 99 \text{ mm}$$

45. (a)

$$\text{Hauling capacity} = \text{Resistance}$$
$$\Rightarrow \quad \mu.\ N.\ W_d = 0.00008\ WV$$
$$\Rightarrow \quad 0.2 \times 3 \times 22 = 0.00008 \times W \times 75$$
$$\Rightarrow \quad W = 2200 \text{ t}$$

48. (d)

Prohibitory signals are regulatory/mandatory signals, not warning signals.

50. (d)

$$\text{Convective acceleration, } a = V\frac{dV}{dx}$$
$$= 2t\left[1-\frac{x}{2L}\right]^2 \times 2t \times 2 \times \left[1-\frac{x}{2L}\right] \times \left(-\frac{1}{2L}\right)$$
$$= \frac{-4t^2}{L}\left[1-\frac{x}{2L}\right]^3$$

At t = 3 sec and x = 0.5 m

$$a = \frac{-4 \times 3^2}{0.8}\left[1-\frac{0.5}{2 \times 0.8}\right]^3$$
$$= -14.623 \text{ m/sec}^2 \simeq -14.62 \text{ m/sec}^2$$

51. (b)

$$h_{air} = h_{water}\left[\frac{\rho_w}{\rho_{air}} - 1\right]$$

$$= 12\left[\frac{1000}{1.2} - 1\right]$$

$$= 9988 \text{ mm} = 9.988 \text{ m}$$

Now,
$$V_{air} = C_d\sqrt{2gh_{air}}$$

$$= 1\times\sqrt{2\times 9.81\times 9.988}$$

$$= 13.99 \text{ m/s}$$

$$\simeq 14 \text{ m/sec}$$

52. (c)

$$\text{Head loss, } h_f = \frac{8Q^2}{\pi^2 g}\cdot\frac{fL}{D^5}$$

For given head loss,

$$Q^2 \propto d^5$$

$\Rightarrow$
$$Q \propto d^{5/2}$$

$$\therefore \text{Percentage reduction in discharge} = \frac{d^{5/2} - (0.9d)^{5/2}}{d^{5/2}}\times 100$$

$$= \left(1 - 0.9^{2.5}\right)\times 100 = \left[1 - (0.81)\times 0.95\right]\times 100$$

$$= [1 - 0.77] \times 100 = 23\%$$

54. (a)

When the acceleration is upward, $a_z = +2.5 \text{ m/sec}^2$

Pressure at any depth 'h' below the free surface is,

$$p = \gamma\cdot h\left[1 + \frac{a_z}{g}\right]$$

$$= \gamma\cdot h\left[1 + \frac{2.5}{10}\right]$$

$$= 1.25\ \gamma h$$

$$\text{Pressure force, } F_H = (1.25\gamma h)\frac{h}{2} = 1.25\times 10\times 1.5\times\frac{1.5}{2}$$

$$= 14.06 \text{ kN/m}$$

55. (c)

$$\text{Mean velocity, } \bar{V} = \frac{-1}{12\mu}\left(\frac{\partial P}{\partial x}\right)\times B^2$$

$$\Rightarrow \quad \left(\frac{-\partial P}{\partial x}\right) = \frac{12\mu\bar{V}}{B^2}$$

$$= \frac{12\times1.05\times10^{-1}\times1.4}{(0.012)^2} = 12250 \text{ Pa/m}$$

$$\therefore \quad \text{Boundary shear stress, } \tau_0 = \left(-\frac{\partial P}{\partial x}\right)\times\frac{B}{2} = 12250\times\frac{0.012}{2} = 73.5 \text{ Pa}$$

56. (d)

$$\text{Discharge, } Q = 6 \text{ m}^3/\text{sec}$$

$$\text{Critical depth, } y_c = \left[\frac{q^2}{g}\right]^{1/3} \qquad \text{where '}q\text{' is discharge intensity in m}^3\text{/s/m}$$

$$= \left[\frac{\left(\frac{6}{4}\right)^2}{9.81}\right]^{1/3} = (0.23)^{1/3} \text{ m}$$

57. (b)

$$\text{Energy loss, } E_L = \frac{(y_2-y_1)^3}{4y_1y_2}$$

$$\Rightarrow \quad \frac{E_L}{y_2} = \frac{\left(1-\frac{y_1}{y_2}\right)^3}{4\times\left(\frac{y_1}{y_2}\right)}$$

$$\Rightarrow \quad \frac{9}{y_2} = \frac{(1-0.028)^3}{4\times0.028}$$

$$\Rightarrow \quad y_2 = \frac{1.008}{0.918} = 1.098 \text{ m}$$

59. (a)

$$\text{Runner power, R.P.} = \rho Q\cdot u(V_1 - u)(1 + k\cos\beta)$$

$$= 1000 \times 0.8 \times 14(29 - 14) \times (1 + \cos15°) \qquad [\because k = 1]$$

$$= 330.29 \times 10^3 \text{ W} = 330.29 \text{ kW}$$

$$\text{Shaft power} = \eta_m \times \text{R.P.}$$

$$= 0.95 \times 330.29 = 313.77 \text{ kW}$$

$$\eta_0 = \frac{S.P.}{\text{Water power}} = \frac{S.P.}{\gamma Q.H}$$

$$= \frac{313.77}{9.81\times0.8\times45} = 0.888 \text{ or } 88.8\%$$

60. (b)

Force exerted on plate,
$$F = \rho a V^2$$
$$= 0.8 \times 1000 \times 0.03 \times 12^2 = 3456 \text{ N}$$

61. (d)

At inlet side of pump, suction is created to lift the water and pressure drops down (sometimes even below vapour pressure) which may leads to cavitation.

62. (b)

$$\tan\alpha \geq 0.9\left[\frac{100q_0}{f_{ck}}+1\right]^{1/2}$$
$$= 0.9\left[\frac{100\times 7}{20}+1\right]^{1/2} = 0.9 \times 36^{1/2} = 5.4$$

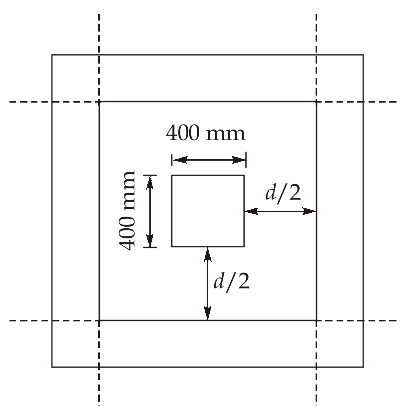
63. (b)

Given : Column load = 1500 kN

Footing size = 15 m^2

Net earth pressure acting due to factored load is
$$w = \frac{\text{Factored column load}}{\text{Area of footing}} = \frac{1500\times 1.5}{15} = 150 \text{ kN/m}^2$$

Punching shear:



The critical section is taken at a distance '$\frac{d}{2}$' from face of column

Two way shear force,
$$V_u = 150[15 - (0.4 + 0.6)^2]$$
$$= 150 \times 14 = 2100 \text{ kN}$$

64. (c)

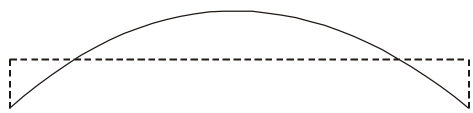
Hoyer system of pre-tensioning is used in mass production of pretensioned member by long line process. Freyssinet system, Magnet Blaton system and Gifford Udall system are type of post tensioning system.

65. **(c)**

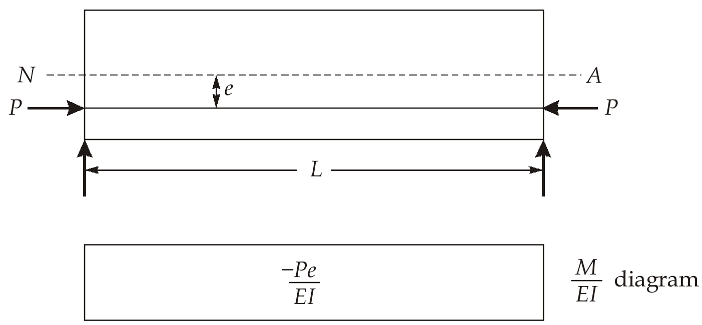
Refer Cl. 19.5.1 and Cl. 20.3.1 of IS 1343 – 2012.

66. **(b)**

To balance the applied load, the pre-stressing cable should be similar to bending moment diagram in order to balance the applied loads effectively.



67. **(a)**



$$\delta_{max} = \frac{-Pe}{EI} \times \frac{L}{2} \times \frac{L}{4}$$

$$= \frac{-PeL^2}{8EI} \quad \text{(–ve sign means upward deflection)}$$

68. **(d)**

Since prestressing is done from both the ends, therefore angle of deviation will be checked from end to centre of tendon.

$$\alpha = 0.04 \text{ radian and } x = \frac{L}{2} = \frac{20}{2} = 10 \text{ m}$$

$$\mu = 0.35,\ k = 0.0015/\text{metre}$$

Loss of pre stress due to friction $= (kx + \mu\alpha) \times$ (Initial stress at end)

$$= [(0.0015 \times 10) + (0.35 \times 0.04)] \times 1000 \text{ N/mm}^2$$

$$= [0.015 + 0.014] \times 1000 \text{ N/mm}^2$$

$$= 29 \text{ N/mm}^2$$

69. **(b)**

As per IS code method, negative moment is $\left(\frac{4}{3}\right)$ times the corresponding positive moment.

$\therefore$ Negative moment coefficient $= \frac{4}{3} \times 0.3 = 0.4$

70. **(b)**

Refer IS 456:2000 Table -12.

71. (c)

Centre of stiffness is the point through which resultant of restoring forces of system passes.

72. (a)

For ordinary moment resisting frame,

$$R = 3 \text{ and for hospital } I = 1.5 \text{ and } \frac{S_a}{g} = 2.5$$

$$\therefore \quad A_h = \frac{ZIS_a}{2Rg} = \frac{0.15 \times 1.5 \times 2.5}{2 \times 3} = 0.09$$

74. (a)

The factor $\sqrt{\frac{A_1}{A_2}}$ is limited to 2.0 because very high axial compressive stresses give rise to transverse tensile strains which may leads to spalling of concrete.

75. (a)

Combined footings also become necessary when an exterior column located along the periphery of the building is so close to the property line that an isolated footing cannot be symmetrically placed without extending beyond that property line.

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