DETAILED SOLUTIONS

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## ESE 2020 : 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-2

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

## DETAILED EXPLANATIONS

### Section A : Transportation Engg. + Building Materials

**4. (d)**

Perimeter method is method of tunneling in hard rock.

**5. (a)**

The staggered joint reduces the centrifugal force on curves.

**6. (b)**

Let $W$ = Weight of the train

and $x$ = Required gradient

$$\text{Resistance due to ruling gradient} = \frac{1}{200}W$$

$$\text{Resistance due to required gradient} = \frac{1}{x}W$$

$$\text{Resistance due to 2 degree curve} = 0.0004 \times 2 \times W$$

So, according to question

$$\frac{W}{x} + 0.0004 \times 2 \times W = \frac{1}{200}W$$

$$\Rightarrow \quad \frac{1}{x} = \frac{21}{5000}$$

$$\Rightarrow \quad \frac{1}{x} = \frac{1}{238.1} \simeq \frac{1}{238}$$

**7. (a)**

$$\left.\begin{aligned} L &= 7.2 \times e = 7.2 \times 15 = 108.0 \text{ m} \\ L &= 0.073\,(CD) \times V_{max} = 0.073 \times 7.5 \times 90 = 49.28 \text{ m} \\ L &= 0.073\, e V_{\max} = 0.073 \times 15 \times 90 = 98.55 \text{ m} \end{aligned}\right\} \text{Max}$$

So, length of transition curve = 108 m

**10. (c)**

Given, One metric chain = 20 m

Let the reference elevation of start point = 100 m

$$2^{nd} \text{ elevation} = 100 + (5-0) \times 20 \times \frac{1}{100} = 101 \text{ m}$$

$$3^{rd} \text{ elevation} = 101 + (15-5) \times 20 \times \left(\frac{-1}{100}\right) = 99 \text{ m}$$

$$4^{rd} \text{ elevation} = 99 + (30-15) \times 20 \times \left(\frac{0.8}{100}\right) = 101.4 \text{ m}$$

$$5^{rd} \text{ elevation} = 101.4 + (40 - 30) \times \left(\frac{0.2}{100}\right) \times 20 = 101.8 \text{ m}$$

$$\text{Maximum difference in elevation} = 101.8 - 99 = 2.8 \text{ m}$$

| Chainage | 0 | 5 | 15 | 30 | 40 |
|---|---|---|---|---|---|
| Elevation (m) | 100 | 101 | 99 | 101.4 | 101.8 |

$$\text{Total turning length, } L = 40 \times 20 = 800 \text{ m}$$

$$\therefore \quad \text{Effective gradient} = \frac{2.8}{800} \times 100 = 0.35\%$$

**12. (d)**

$$e = 0$$

$$f = \frac{V^2}{127R}$$

$$= \frac{50^2}{127 \times 100} = 0.197$$

**13. (a)**

$$e = \frac{V^2}{225R} = \frac{80^2}{225 \times 480} = 0.059$$

Since this value of $e$ is less than 0.07, the super-elevation of 0.059 may be adopted.

Raising of outer edge with respect to the inner edge of pavement

$$E = Be = 7.5 \times 0.059 = 0.44 \text{ m}$$

**14. (a)**

$$\text{Minimum space headway, } S = 0.278 \times Vt + L$$

$$= 0.278 \times 40 \times 0.7 + 5$$

$$= 12.784 \text{ m}$$

$$\text{Theoretical capacity, } q_c = \frac{1000V}{S}$$

$$= \frac{1000 \times 40}{12.784} = 3128 \text{ veh/hr}$$

**15. (d)**

$$y_a = \frac{q_a}{S_a} = \frac{400}{1250} = 0.32$$

$$y_b = \frac{q_b}{S_b} = \frac{250}{1000} = 0.25$$

$$Y = y_a + y_b = 0.32 + 0.25 = 0.57$$

$$\text{Total lost time, } L = 2n + R$$

$$= 2 \times 2 + 12$$

$$= 16 \text{ sec}$$

$$\text{Optimum cycle time, } C_0 = \frac{1.5L+5}{1-Y} = \frac{1.5\times16+5}{1-0.57}$$

$$= \frac{29}{0.43} = 67.4 \text{ sec}$$

**16. (d)**
All the given points are the functions of traffic engineering department.

**21. (d)**
Lime mortar gives a fairly strong surface finish.

**22. (d)**
Fat lime sets slowly in the presence of air.

**23. (d)**
Soft woods are lighter in colour as compared to hardwood.

**25. (b)**
Blowing agent such as sodium bicarbonate are added to plastic to produce porous articles.

**26. (b)**
Distemper is most suitable for plastered surfaces as well as white washed surface of interior walls.

**27. (a)**
Barium hydrate is a chemical compound used to protect stones in industrial towns.

**29. (c)**
Chuff is referred as the deformation of the shape of bricks caused by the rain water falling on hot bricks.

**31. (c)**
Bleeding of concrete occurs when cement paste rises to the surface of concrete.

**32. (b)**
Strain determination is obtained from secant modulus. So, option (b) is correct.

**33. (b)**
Concrete is assumed as a Bingham fluid.

**34. (c)**
**IS 9142 : 1979** specifications for artificial lightweight aggregates for concrete masonry units.

**36. (c)**
The load is applied perpendicular to the axis of the cylindrical specimen.

**37. (d)**
23% water is required for complete hydration and 15% is required to fill the gel pores.

**38. (d)**
Deciduous trees are better for obtaining timber for construction purposes.

**Section B : Flow of fluids, hydraulic machines and hydro power**

**40. (d)**

$$\mu = \nu.\rho = 3.7 \times 10^{-4} \times 0.85 \times 1000$$
$$= 0.3145 \text{ Pa.s}$$

Shear stress, $\tau = \mu \frac{du}{dy} = \mu \frac{V}{h}$

$$= 0.3145 \times \frac{0.15}{\frac{(25.018 - 25)}{2 \times 10^2}}$$

$$= 524.17 \text{ N/m}^2$$

Frictional resistance, $F_s = A\,\tau$

$\Rightarrow$ $F_s = \pi DL \times \tau$

$$= \pi \times \frac{25}{100} \times 3.3 \times 524.17$$

$$= 1358.55 \text{ N}$$
$$= 1.36 \text{ kN}$$

**41. (d)**

The capillary rise, $h = \frac{4T\cos\theta}{\rho g d}$

$\because$ $\cos 130° = \cos(90° + 40°) = -\sin 40°$

$\therefore$ $h = -\frac{4 \times 0.48 \times (0.643)}{13600 \times 9.81 \times 3 \times 10^{-3}}$

$$= -3.08 \times 10^{-3} \text{ m} = -3.08 \text{ mm}$$

Therefore, there is capillary depression of 3.08 mm.

**42. (d)**

Rotational stability of a completely submerged body:

| | |
|---|---|
| G lies below B | Stable equilibrium |
| G lies above B | Unstable equilibrium |
| G coincides with B | Neutral equilibrium |

Rotation stability of floating body:

In this case, the stability of the body not only depends on the relative position of the centre of gravity and centre of buoyancy but also depends on the position of metacentre relative to the centre of gravity.

| | |
|---|---|
| G lies below M | Stable equilibrium |
| G lies above M | Unstable equilibrium |
| G coincides with M | Neutral equilibrium |

In case of liquid mass subjected to vertical acceleration,

$$\frac{\partial p}{\partial z} = -\gamma\left(1+\frac{a}{g}\right) = -p \cdot g_{eff} \qquad [g_{\text{eff}} = (g + a)]$$

**43. (a)**

Hydraulic gradient line gives the sum of datum head and the pressure head.

In a gradual contraction, the velocity of flow increases and the pressure decreases. The flow is from higher to lower pressure, which eliminates the causes of turbulence following formation of eddies. The loss of energy in a gradual contraction (also called as reducer) is due to friction mainly, and the resistance (energy loss) offered by a reducer is always less than that of a similar diffuser.

**44. (a)**

In this case the sea around the torpedo is stationary and the torpedo is in motion. Hence, this is an unsteady flow motion. However, this could be converted to equivalent steady motion by considering relative fluid motion. The torpedo is considered to be stationary and the sea water is assumed to move with an approach velocity of 25 m/s. The pressure at the nose of the torpedo is the stagnation pressure corresponding to this approach velocity.

Applying Bernoulli's equation,

$$\frac{P_0}{\rho g} + z_0 + \frac{V_0^2}{2g} = \frac{P_s}{\rho g} + z_s + \frac{V_s^2}{2g}$$

Where,

$0_{\text{denotes approach flow}}$

$S_{\text{denote the stagnation point}}$

$\therefore \quad Z_0 = Z_s = 0$

$$\therefore \quad \frac{P_s}{\rho g} = \frac{P_0}{\rho g} + \frac{V_0^2}{2g}$$

$$= 15 + \frac{25^2}{2 \times 9.81} = 46.86 \text{ m}$$

$$\therefore \quad P_s = \frac{46.86 \times 1025 \times 9.81}{1000} = 471.2 \text{ kN/m}^2$$

**45. (c)**

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

**46. (d)**

$\because$ For triangular channel,

$$y_c = \frac{4}{5} E_{\min}$$

$$= \frac{4}{5} \times 2 = 1.6 \text{ m}$$

$$E_{min} = y_c + \frac{V_c^2}{2g}$$

$$\Rightarrow \quad 2 = 1.6 + \frac{V_c^2}{2 \times 9.81}$$

$$\Rightarrow \quad V_c = 2.8 \text{ m/s}$$

**47. (c)**

Let $x$ be the distance from the leading edge

$$\therefore \quad F_{Dx} = \frac{1}{2} F_{DL}$$

$$= C_{Dfx}(B.x) \cdot \frac{\rho U^2}{2}$$

$$F_{DL} = C_{DfL}(B.L) \cdot \frac{\rho U^2}{2}$$

$$\therefore \quad \frac{C_{Dfx}}{C_{DfL}} \cdot \frac{x}{L} = \frac{F_{Dx}}{F_{DL}} = \frac{1}{2}$$

But $$C_{Dfx} = \frac{1.328}{\sqrt{R_{ex}}} = \frac{1.328}{\sqrt{\frac{U.x}{\nu}}}$$

and $$C_{DfL} = \frac{1.328}{\sqrt{\frac{U.L}{\nu}}}$$

$$\therefore \quad \left(\frac{L}{x}\right)^{1/2} \cdot \frac{x}{L} = \frac{1}{2}$$

$$\Rightarrow \quad x = \frac{1}{4} L$$

**48. (b)**

$$H = 600 \text{ m}$$

$$V_1 = C_V \sqrt{2gH}$$

$$= 0.98 \times \sqrt{2 \times 10 \times 600}$$

$$= 107.35 \text{ m/s}$$

$$Q = \frac{\pi}{4} \times 0.18^2 \times 107.35 = 2.73 \text{ m}^3/\text{s}$$

$$P = \eta_0 (\rho Q g H)$$

$$= 0.85 \times 1000 \times 10 \times 2.73 \times 600 \times 10^{-3} \text{ kW}$$

$$= 13923 \text{ kW}$$

**49. (c)**

$$\text{Flow depth, } y_1 = 2 \text{ m}$$

$\because$ Surge height = 0.5 m

So $y_2 = 2 + 0.5 = 2.5$ m

$\therefore$ $y_1 + y_2 = 4.5$ m

$$\text{Celerity, } C_s = \pm\sqrt{\frac{g}{2}\cdot\frac{y_2}{y_1}(y_1 + y_2)}$$

$$= \pm\sqrt{\frac{1}{2}\times 9.81\times\frac{2.5}{2}\times 4.5}$$

$$= \pm 5.25 \text{ m/s}$$

**50. (b)**

$$V_0 = C\sqrt{2g\left(\frac{P_s - P_0}{\rho g}\right)}$$

$$= 0.98\sqrt{\frac{2\times[3-(-3)]}{1.2}\times 10^3}$$

$$= 98 \text{ m/s}$$

**51. (c)**

$$\text{Head loss in converging cone, } H_{L_1} = \left(1 - C_d^2\right)\cdot \Delta h$$

$$\Delta h = y\left(\frac{S_m}{S_p} - 1\right) = 0.2\left(\frac{13.6}{1} - 1\right)$$

$$= 2.52 \text{ m}$$

$\therefore$ $$H_{L_1} = \left(1 - 0.96^2\right)\times 2.52$$

$$= 0.198 \text{ m}$$

$$\text{Head loss in diverging cone, } H_{L_2} = 10\times\frac{V^2}{2g} = 10\times\frac{1.1^2}{2\times 2.98} = 0.62 \text{ m}$$

$$\text{So, total head loss} = H_{L_1} + H_{L_2} = 0.198 + 0.62 = 0.82 \text{ m}$$

**52. (d)**

$\because$ $$h_f = \frac{8fLQ^2}{\pi^2 g D^5} = \frac{fLQ^2}{12.1D^5}$$

$\because$ Pipes are in series so discharge will be same.

$$\frac{h_{f_1}}{h_{f_2}} = \frac{L_1}{D_1^5} \times \frac{D_2^5}{L_2}$$

$$= \frac{L_1}{32L_1} \times \frac{(2D_1)^5}{D_1^5}$$

$$= \frac{2^5}{32} = 1$$

**53. (c)**

Given:

$$\text{Diameter} = 10 \text{ cm} = 0.1 \text{ m}$$

$$f = 0.035$$

$$R_e = 10^5$$

The thickness of the laminar sublayer $\delta'$ is

$$\delta' = \frac{11.6\nu}{V^*}$$

$$V^* = \sqrt{\frac{f}{8}} \cdot V$$

$$Re = \frac{VD}{\nu}$$

$$\nu = \frac{VD}{\text{Re}}$$

$$\delta' = \frac{11.6 \times \frac{VD}{\text{Re}}}{\sqrt{\frac{f}{8}} \cdot V} = \frac{11.6 \times D}{\text{Re}\sqrt{\frac{f}{8}}}$$

$$\delta' = \frac{11.6 \times 0.1}{\sqrt{\frac{0.035}{8}} \times 10^5} = 1.75 \times 10^{-4} \text{ m} = 0.175 \text{ mm}$$

**54. (b)**

Stall angle is the maximum angle of attack if the angle of attack increases further the lift decreases rapidly.

**56. (c)**

The velocity distribution is logarithmic in turbulent boundary layer.

## Section C : Design of concrete and Masonry Structures-2

**57. (a)**

1st statement is in accordance with **Clause 12.1.7.1** of **IS 1343:2012**.

According to **Clause 12.1.7.2** of **IS 1343:2012**, in case of cables or large bars, the minimum clear spacing shall not be less than the largest of the following:

(a) 40 mm

(b) Maximum size of cable or bar, and

(c) Nominal maximum size of aggregate plus 5 mm.

**58. (c)**

$$L = 30000 \text{ mm}$$
$$P_0 = 1000 \text{ N/mm}^2$$
$$\text{Slip} = 2 \text{ mm}$$

$$\text{Loss of prestress} = \frac{\delta l}{l} \times E_S = \frac{2}{30000} \times 200 \times 10^3$$
$$= 13.33 \text{ N/mm}^2$$

$$\%\text{Loss of prestress} = \frac{13.33}{1000} \times 100 = 1.33\%$$

**59. (a)**

$$R_D = \frac{1}{\left|1 - \left(\frac{w}{w_n}\right)^2\right|}$$

$$w_n = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi \text{ rad/s}$$

$$R_D = \frac{1}{\left|1 - \left(\frac{3\pi}{\pi}\right)^2\right|} = \frac{1}{8}$$
$$= 0.125 \text{ or } 12.5\%$$

**60. (c)**

- Given, $P$ = 2300 kN, $q_a$ (gross) = 300 kN/m²

Assuming the weight of the (footing + backfill) to be 10% of the column load

$$\text{Base area required} = \frac{2300 \times 1.1}{300} = 8.43 \text{ m}^2$$

$$\text{Area provided} = 3 \text{ m} \times 3 \text{ m} = 9 \text{ m}^2 > 8.43 \text{ m}^2 \quad \text{OK}$$

- Net soil pressure at ultimate loads

$$q_u = \frac{2300 \times 1.5}{3.0 \times 3.0} = 383 \text{ kN/m}^2 = 0.383 \text{ N/mm}^2$$

- For one way shear, critical section is at a distance $d$ from the column face

∴ Shear resistance, $V_C = 0.36 \times 3000 \times d$

For footing to be safe in one-way shear,

$$V_C \geq V_U$$

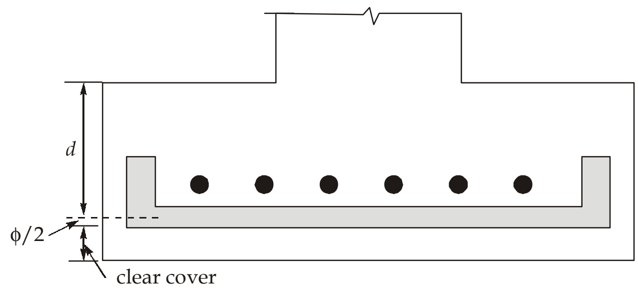
$$\Rightarrow \quad 0.36 \times 3000 \times d \geq 0.383\,(3000) \times (1275 - d) \qquad \left[\frac{3000 - 450}{2} = 1275 \text{ m}\right]$$

$$d \geq 657.2 \text{ mm} \simeq 658 \text{ mm (say)}$$

Providing a clear cover of 75 mm,

$$D \geq \left(658 + 75 + \frac{16}{2}\right) \text{ mm}$$

$$\geq 741 \text{ mm}$$




**61. (c)**

- Cantilever wall is generally economical for heights upto 8 m.
- Although buttresses are structurally more efficient (and more economical) than counterforts, the counterfort wall is generally preferred to the buttress wall as it provides free usable space (and better asthetics) in front of the wall.

**62. (c)**

$$\text{Moment of resistance} = \frac{W_u l^2}{24}$$

$$\text{Self weight of slab} = 0.14 \times 25 = 3.5 \text{ kN/m}^2$$

$$\text{Service load} = 7.5 \text{ kN/m}^2$$

$$\text{Ultimate load} = 1.5 \times (3.5 + 7.5)$$

$$= 16.5 \text{ kN/m}^2$$

$$\text{Ultimate moment capacity} = \frac{16.5 \times 5^2}{24} = 17.187 \text{ kNm/m}$$

**63. (b)**

The sum of nodel forces at any yield line intersection in a slab is zero.

**64. (c)**

Under ground a walls are subjected to soil pressure and hence are designed as retaining walls with or without surcharge depending on condition.

**65. (a)**

**IS 456 : 2000 Clause 24.1** recommends the following span to depth ratio values.

| | Fe 250 | Fe 415 |
|---|---|---|
| Simply supported two-way slabs | 35 | 28 |
| Continuous two-way slabs | 40 | 32 |

**66. (b)**

$$M = \frac{P(L-b)^2}{BL}$$

$$P = \text{Design load} = 1.5\,DL + 1.5\,LL$$
$$= 1.5\ (1400) = 2100 \text{ kN}$$

Factored soil pressure acting on footing $= \dfrac{2100}{(2.8)^2} = 268 \simeq 270 \text{ kN/m}^2$

$$M = \frac{270 \times (2.8-0.4)^2}{2 \times 4} \times 2.8 = 544.32 \text{ kNm}$$

$$d = \sqrt{\frac{M}{0.138 f_{ck} b}} = \sqrt{\frac{544.32 \times 10^6}{0.138 \times 20 \times 2800}} = 265.4 \text{ mm}$$
$$\simeq 270 \text{ mm (say)}$$

**67. (a)**

Since $\dfrac{L}{B}$ ratio of slab $= \dfrac{9}{3.5} = 2.57 > 2,$ the slab will be designed as a one way slab.

Shorter span will be used for moment calculations.
Effective span is the lesser of the following:
(i) Clear span + Effective depth = 3.5 + 0.14 = 3.64 m
(ii) c/c distance between the supports = 3.5 + 0.23 = 3.73 m
Hence, effective depth = 3.64 m

**68. (b)**

In Magnel Blaton system, anchorage is provided by pairs of wires held by flat steel wedges in sandwich plates bearing on distribution plates.

**69. (c)**

$\because$ Depth of footing $= \dfrac{P}{\gamma}\left(\dfrac{1-\sin\phi}{1+\sin\phi}\right)^2$

$$= \frac{150}{18}\left(\frac{1-\sin 30°}{1+\sin 30°}\right)^2 = \frac{150}{18}\left(\frac{1}{3}\right)^2 = 0.92 \text{ m}$$

**70. (a)**

**IS 1905 :** Code of practice for structural use of unreinforced masonry.
**IS 1893 :** Criteria for earthquake resistance design of structures.
**IS 13920 :** Ductile detailing of reinforced concrete structures.
**IS 3343 :** Natural moulding sand for use in foundaries.
**IS 1343 :** Code of practice for prestress concrete.

**71. (b)**

Refer table 4 of **IS 1905-1987**.

**72. (d)**

A parabolic tendon carrying a tension *P* will provide an upward uniformly distributed load or pressure which is given by

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

$$= \frac{8 \times 1000 \times 200 \times 10^{-3}}{(10)^2}$$

$$= 16 \text{ kN/m}$$

$\therefore$ Net downward loading $= 20 - w_c$

$$= 20 - 16 = 4 \text{ kN/m}$$

**73. (c)**

$$\text{Base shear} = A_n \times w$$

$$= \left(\frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}\right) \times w$$

$$= \left(\frac{0.16}{2} \times \frac{1.5}{5} \times 0.36\right) \times 5000$$

$$= 43.2 \text{ kN}$$

**74. (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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