DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 6

Section A : Design of Steel Structure + Surveying and Geology

Section B : Solid Mechanics - 1

Section C : Geo-Technical & Foundation Engineering-2 + Environmental Engineering-2

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

DETAILED EXPLANATIONS

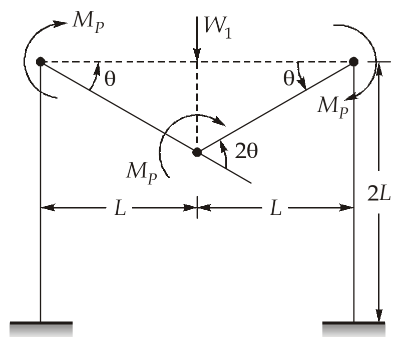
1. (b)

Margin of safety (MOS) is defined for brittle materials only

$$MOS = \frac{\text{Ultimate stress}}{\text{Working stress}} - 1$$

2. (c)

Beam mechanism:

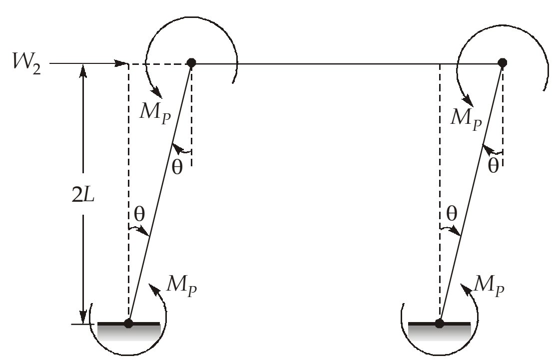


$$\text{External workdone} = \text{Internal work done}$$

$\Rightarrow$ $$W_1(L\theta) = M_p\theta + M_p(2\theta) + M_p(\theta)$$

$\Rightarrow$ $$W_1 = \frac{4M_P}{L}$$

Sway mechanism:



$$\text{External workdone} = \text{Internal workdone}$$

$\Rightarrow$ $$W_2(2L\theta) = M_p\theta + M_p\theta + M_p\theta + M_p\theta$$

$\Rightarrow$ $$W_2 = \frac{2M_P}{L}$$

Now, $$\frac{W_1}{W_2} = \frac{\frac{4M_P}{L}}{\frac{2M_P}{L}} = 2$$

3. (c)

As per Cl 3.7.1 of IS 800 : 2007, local buckling can be avoided before the limit state is achieved by limiting the width to thickness ratio of each element of a cross-section subjected to compression due to axial force, moment or shear.

5. (b)

- Nominal diameter of bolt = 22 mm

Then, diameter of bolt hole = 22 + 2 = 24 mm

- Minimum pitch = 2.5 × 22 = 55 mm
- Minimum end/edge distance = 1.5 × 24 = 36 mm
- Let, n be the number of bolts, then

$$2 \times 36 + (n - 1)55 = 200$$

$$\Rightarrow \quad n = 3.327$$

Therefore, maximum 3 number of bolts can be provided.

6. (a)

$$I = Ak^2$$

where, I is moment of inertia of bar.

A is crossectional area of bar.

k is radius of gyration.

$$\therefore \quad k = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{\pi}{64}D^4}{\frac{\pi}{4}D^2}} = \frac{D}{4} = \frac{20}{4} = 5 \text{ mm}$$

Now, slenderness ratio (γ) for hanger bar is 160.

Now, $$\gamma = \frac{l_e}{k} = 160$$

$$l_e = 160 \times 5 \text{ mm} = 800 \text{ mm}$$

7. (b)

Load carried by lacing = 2.5% of axial load

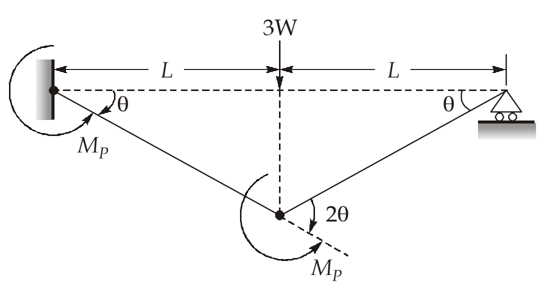
$$= \frac{2.5}{100} \times 200 = 5 \text{ kN}$$

8. (c)

The cost of truss for economical spacing is given as

$$t = 2p + r = 2 \times 40 + 25 = \text{Rs. } 105 \text{ per unit area}$$

9. (a)

- Number of plastic hinges, $n = D_s + 1 = 1 + 1 = 2$
- 

- $$\text{External workdone} = \text{Internal workdone}$$

$\Rightarrow$ $$(3W)(L\theta) = M_p\theta + M_p(2\theta)$$

$\Rightarrow$ $$3WL\theta = 3M_p\theta$$

$\Rightarrow$ $$W = \frac{M_P}{L}$$

10. (c)

Buckling curve	Imperfection factor
a	0.21
b	0.34
c	0.49
d	0.76

12. (a)

- $$F_1 = \frac{\Sigma\text{Forces}}{\text{Number of bolts}} = \frac{2P+2P}{4} = P$$
- F_2 is the force due to moment but force due to moment is balancing each other.

$\therefore$ $$F_{resultant} = \sqrt{(F_1)^2 + (F_2)^2 + 2F_1 \cdot F_2 \cdot \cos\theta}$$
$$= F_1 = P$$

13. (c)

IS : 875 : 2007 specifies the following live loads to be considered in the analysis of an industrial building:

Roof slope	**Access**	**Live load**
$\leq 10°$	Provided	1.5 kN/m^2 of plan area
	Not provided	0.75 kN/m^2 of plan area
$> 10°$		For roof membrane sheets or purlins: 0.75 kN/m^2 less 0.02 kN/m^2, for every degree increase in slope over 10° $\not<$ 0.4 kN/m^2

So, the live load for an inclination 21° is given as

$$w_L = 0.75 - 0.02\,(21 - 10)$$
$$= 0.53\ kN/m^2 = 530\ N/m^2$$

14. (a)

- $$\text{Design wind speed, } V_z = k_1 \times k_2 \times k_3 \times V_b = 1 \times 0.9 \times 1 \times 50$$
$$= 45\ m/s$$

Now, $$\text{Design wind pressure, } p_d = 0.6 \times V_z^2 = 0.6 \times (45)^2 = 1215\ N/m^2$$

15. (c)

For torsion resistance, the area of the section should be away from the axis of the section and it should be symmetrical about the axes. Therefore box type section is the most desirable.

18. (d)

Maximum size of fillet weld at a rounded edge is given as:

$$S_{max} = \frac{3}{4} \times \text{Thickness of plate}$$

$$= \frac{3}{4} \times 12 = 9 \text{ mm}$$

19. (a)

$$\text{Pull correction, } C_p = \frac{(P_m - P_o)L}{AE} = \frac{100-50}{4\times 2\times 10^5} \times 30 = 1.875 \times 10^{-3} \text{ m}$$

$$\text{Corrected length} = 30.001875 \text{ m}$$

$$\text{Correction for MSL} = -\frac{hL}{R} = \frac{-2000\times 30.001875}{6400\times 1000} = -9.375\times 10^{-3} \text{ m}$$

∴ Corrected length = 30.001875 – (9.375 × 10^{-3}) = 29.9925 m

∴ Total correction = (30 – 29.9925) × 10^{-3} m = 7.5 mm

21. (b)

Declination = 3°30′W

Magnetic bearing of line AB = S56°30′ W = 236°30′

True bearing of line AB = 236°30′ – 3°30′ = 233° = S53° W

22. (a)

$$\text{Scale of photograph} = \frac{f}{H} = \frac{0.2}{1600} = \frac{1}{8000}$$

Mean base length in the photograph,

b = 102.5 mm

$$\text{Actual base length, } B = \frac{bH}{f} = 102.5\times\frac{1600}{200} = 820 \text{ m}$$

$$\text{Parallax, } P = \frac{Bf}{H-h}$$

$$\text{Parallax at bottom} = \frac{820\times 200}{1600} = 102.5 \text{ mm}$$

And,
$$\text{Parallax at top} = \frac{820\times 200}{(1600-30)} = 104.46 \text{ mm}$$

∴ Difference in parallax = 104.46 – 102.5 = 1.96 mm

23. (b)

$$\text{Central angle } (\theta) = \frac{d}{R\sin 1} = \frac{980}{30.91} = 31.7''$$

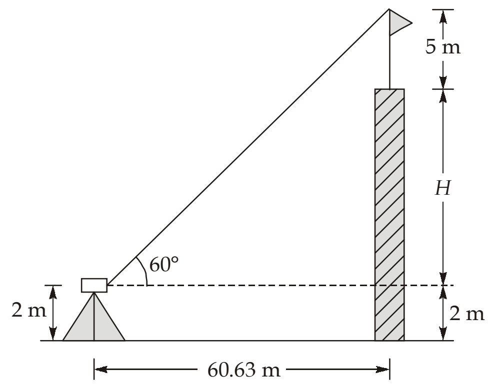
$$\text{Angular correction for curvature} = \frac{\theta}{2} = \frac{31.7''}{2} = 15.85''$$

$$\text{Angular correction for refraction} = \frac{md}{R\sin 1''} = \frac{0.075\times 980}{30.91} = 2.38''$$

$\therefore$ Combined correction = Correction of curvature – Correction for refraction

$= 15.85'' - 2.38'' = 13.47''$

25. (c)

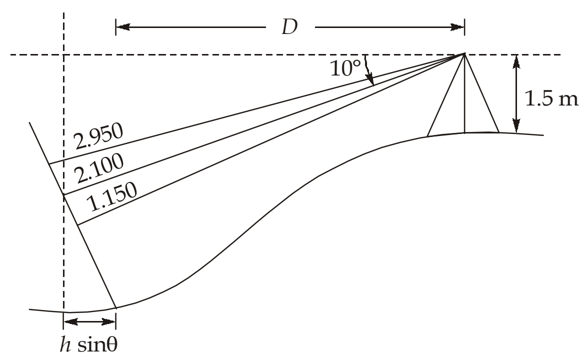


$$\tan 60° = \frac{H+5}{60.63}$$

$\Rightarrow$ $H = 60.63 \times \tan 60° - 5 = 100$ m

$\therefore$ Total height of building $= H + 2 = 100 + 2 = 102$ m

26. (a)



$D = (kS + C)\cos\theta - h\sin\theta$

$= [100 \times (2.950 - 1.150) + 0] \times \cos 10° - 2.100 \sin 10°$

$= 177.26 - 0.36 = 176.90$ m

29. (b)

Zenith distance $= 180° - (\theta + \delta) = 180° - [42°50' + 83°40']$

$= 180° - 126°30' = 53°30'$

32. (c)

Normal equation for A:

$1 \times A = 40°20'15''$ ... (i)

$2 \times 2A = 161°21'40''$ ... (ii)

$4 \times 4A = 645°25'20''$ ... (iii)

Adding above three equations, we get

$21A = 847°07'15''$

$A = 40°20'20.7''$

33. (d)

$$\Delta h_{AB} = \frac{(0.725-1.405)+(1.625-2.545)}{2} = -0.8 \text{ m}$$

$$c = -0.0673 \times 1^2 = -0.0673 \text{ m}$$

Now, $\Delta h_{AB} = a_1 - (b_1 - e)$

$\Rightarrow$ $-0.8 = 1.625 - 2.545 + e$

$\Rightarrow$ $e = +0.12$ m

$\therefore$ Collimation error, $e_c = e - 0.0673\, d^2 = 0.12 - 0.0673$

$= 0.0527 \text{ m} = 5.27 \text{ cm} \simeq 5.3 \text{ cm}$

35. (c)

Putting level midway between backsight and foresight will lead to elimination of collimation error in both of the cases i.e. whether line of collimation is inclined upwards or downwards.

36. (b)

An error will occur if the clamp screws are not properly tightened. The magnitude of error will depend upon the slip. The error can be avoided by properly tightening the screws. The slip also occurs when the shifting head is not properly tightened or when instrument is not properly fixed to the tripod head.

38. (d)

Shear failure, splitting failure and bearing failure of plates are due to insufficient end distance. By providing proper end distance, we can prevent these three failures of plate.

39. (b)

$$\varepsilon = \begin{bmatrix} 10 & 6 \\ 6 & 12 \end{bmatrix} \times 10^{-3}$$

$\Rightarrow$ $\varepsilon_x = 10 \times 10^{-3}$, $\varepsilon_y = 12 \times 10^{-3}$, and $\frac{\phi_{xy}}{2} = 6 \times 10^{-3}$

$\because$ $$\varepsilon_\theta = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta + \frac{\phi_{xy}}{2}\sin 2\theta$$

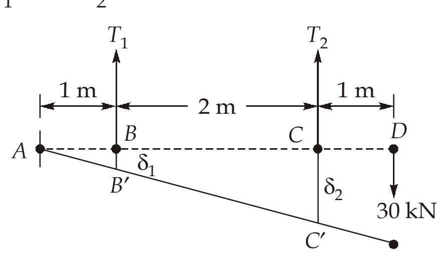
Here, $\theta = -45°$

$\therefore$ $$\varepsilon_{45°} = \left[\left(\frac{10+12}{2}\right) + \left(\frac{10-12}{2}\right)\cos 90° - 6\sin 90°\right] \times 10^{-3}$$

$= [11 - 0 - 6] \times 10^{-3} = 5 \times 10^{-3}$

40. (a)

After application of load, let, T_1 and T_2 be the tension in wires BE and CF respectively.



At end A, $\Sigma M_A = 0$

$\Rightarrow$ $T_1(1) + T_2(3) - 30\,(4) = 0$

$\Rightarrow$ $T_1 + 3T_2 = 120$ ... (i)

Also, $\frac{\delta_1}{\delta_2} = \frac{AB}{AC} = \frac{1}{3}$ [$\because$ ΔABB′ ~ ΔACC′]

$\Rightarrow$ $3\delta_1 = \delta_2$

$\because$ Wires BE and CF are identical,

$\therefore$ $3\left[\frac{T_1 L}{AE}\right] = \frac{T_2 L}{AE}$

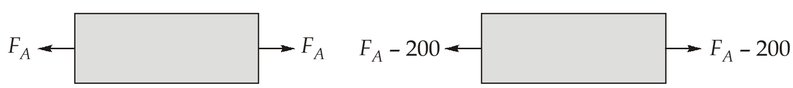
$\Rightarrow$ $T_2 = 3T_1$ ... (ii)

From (i) and (ii), $10T_1 = 120$

$\Rightarrow$ $T_1 = 12$ kN

41. (c)

FBD of AB and BC are shown below:



Net expansion in axial direction $= 0$

$$\Rightarrow \frac{F_A \times L_{AB}}{AE} + \frac{(F_A - 200)\times L_{BC}}{AE} = 0$$

$\Rightarrow$ $F_A \times 1 + (F_A - 200) \times 3 = 0$

$\Rightarrow$ $F_A + 3F_A = 600$

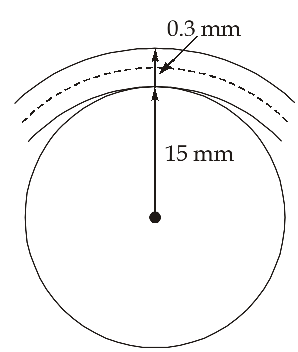
$\Rightarrow$ $F_A = 150$ kN

Now, Stress in AB, $\sigma_{AB} = \frac{150 \times 10^3 \times 4}{\pi \times 50^2} = \frac{240}{\pi}\ \text{N/mm}^2$

42. (a)

Maximum bending stress, $\sigma = \frac{M}{Z}$, which is independent of E.

43. (b)



From the bending equation, $\frac{\sigma}{y} = \frac{E}{R} = \frac{\sigma_{max}}{y_{max}}$

$$\Rightarrow \frac{\sigma_{max}}{0.3/2} = \frac{120 \times 10^3}{\left(\frac{30}{2} + \frac{0.3}{2}\right)}$$

$\Rightarrow$ $\sigma_{max} = 1188.11\ \text{N/mm}^2$

44. (a)

Let V_A and V_E be the vertical reactions at A and E respectively. Considering equilibrium,

$\Sigma M_E = 0$

$\Rightarrow$ $V_A(8) - 3(2)(1) - 8(2) = 0$

$\Rightarrow \quad V_A(8) = 22$

$\Rightarrow \quad V_A = 2.75$ kN

$\therefore$ BM at mid-span of AB = $V_A(2) = 2.75 \times 2 = 5.5$ kN-m

45. (c)

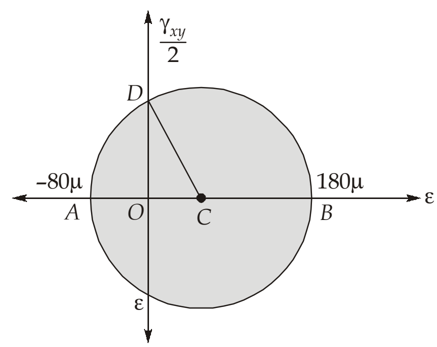
Annealing is a heat treatment process, to increase ductility and reduce the hardness.

46. (c)

$$\text{Volumetric strain energy, } U_v = \frac{1-2\mu}{6E}(\sigma_x + \sigma_y + \sigma_z)^2 = \frac{(1-2\times 0.3)}{6\times 2\times 10^5}(120-70+0)^2$$

$$= \frac{0.4\times 2500}{12\times 10^5}\times 10^6 = 833.33\ \text{N/m}^2$$

48. (a)



Maximum shear strain = AB = [180 + 80] μ = 260μ

$$\text{Radius, CD} = \frac{AB}{2} = 130\mu$$

$$\text{Centre Co-ordinates of } C = \left[\frac{180\mu - 80\mu}{2}, 0\right] = [50\mu, 0]$$

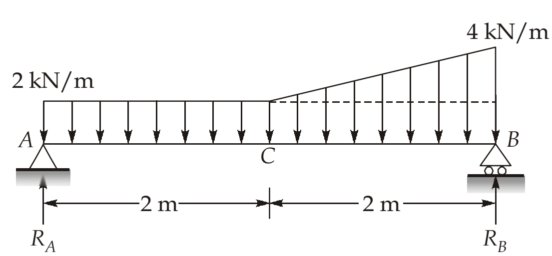
$\therefore \quad OC = 50\mu$

$\therefore \quad OD = \sqrt{CD^2 - OC^2}$

$$\Rightarrow \quad \frac{\gamma_{xy}}{2} = \left(\sqrt{130^2 - 50^2}\right)\mu = 120\mu$$

$\Rightarrow \quad \gamma_{xy} = 240\mu$

49. (c)



Considering equilibrium, $\Sigma M_B = 0$

$$R_A(4) - 2\times4\times2 - \frac{1}{2}(2)(2)\left(\frac{2}{3}\right) = 0$$

$$4R_A - 16 - \frac{4}{3} = 0$$

$$\Rightarrow \quad R_A = \frac{1}{4}\times\left(\frac{52}{3}\right) = \frac{13}{3}\text{ kN} = 4.33 \text{ kN}$$

∴ Shear force at C, $\quad V_C = R_A - 2(2) = 4.33 - 4 = 0.33$ kN

54. (a)

The factor of safety is given as

$$\text{FOS} = \frac{C_u N'_C}{\gamma D_f}$$

where, $\quad N'_C = 5\left[1+0.2\frac{D_f}{B}\right] = 5\left[1+0.2\frac{7}{3.2}\right] = 7.19$

Now, $\quad \text{FOS} = \frac{42\times7.19}{21\times7} = 2.054 \simeq 2.05$

55. (b)

A foundation is considered shallow if

$$\frac{\text{Depth}}{\text{Width}} \le 1$$

56. (d)

$$\text{Cohesion, } C_u = \frac{UCS}{2} = \frac{100}{2} = 50\text{ kN/m}^2$$

Now, ultimate load capacity of pile Q_u is given as

$$Q_u = (9C)(B\times B) + (\alpha C)(4BL)$$

$$= (9\times50)(0.5\times0.5) + (0.8\times50)(4\times0.5\times10)$$

$$= 912.5 \text{ kN}$$

57. (c)

Pile load capacity is given by

$$Q = \frac{166.64E}{S+2.54} = \frac{166.64\times40}{2.46+2.54} = 1333.12\text{ kN}$$

58. (a)

The settlement of footing on a granular soil is given as

$$S_F = S_P\left[\frac{B_F(B_P+0.3)}{B_P(B_F+0.3)}\right]^2$$

$$= 21\left[\frac{1.8}{0.3}\times\frac{(0.3+0.3)}{(1.8+0.3)}\right]^2 = 61.71\text{ mm}$$

60. (b)

Maximum depth, H is given as

$$H = \frac{C_u}{\gamma \cdot S_n} = \frac{50}{20 \times 0.261} = 9.5785 \simeq 9.58 \text{ m}$$

62. (b)

- The outside clearance should be as small as possible for reducing the driving force.
- The area ratio is defined as, $A_r = \frac{\text{Maximum cross-sectional area of cutting edge}}{\text{Area of soil sample}} \times 100$

63. (c)

$$(\text{BOD})_5 = [\text{Initial DO} - \text{Final DO}]_{\text{mix}} \times \text{D.F.}$$

$$\Rightarrow \quad 80 = \left[(DO_i) - 3.7\right] \times \frac{100}{6}$$

$$\Rightarrow \quad (\text{DO}_i)_{\text{mix}} = 8.5 \text{ mg}/l$$

Now,

$$(\text{DO}_i)_{\text{mix}} = \frac{6 \times 0.7 + 94 \times (DO)_i}{100}$$

$$\Rightarrow \quad 8.5 = \frac{4.2 + 94 \times (DO)_i}{100}$$

$$\Rightarrow \quad (\text{DO})_i = 8.99 \simeq 9 \text{ mg}/l$$

64. (a)

The decolourisation is caused by anaerobic bacteria.

67. (c)

According to Manning's formula,

$$V_1 = \frac{1}{n}(R_1)^{2/3}(S_1)^{1/2} = 1 \text{ m/s}$$

$$\Rightarrow \quad V_1 = \frac{1}{n}\left(\frac{D_1}{4}\right)^{2/3}(S_1)^{1/2} = 1 \text{ m/s}$$

Now, $D_2 = 2D_1$, and $S_2 = 2S_1$

$$\therefore \quad V_2 = \frac{1}{n}\left(\frac{2D_1}{4}\right)^{2/3}(2S_1)^{1/2} = (2)^{\left(\frac{2}{3}+\frac{1}{2}\right)} \frac{1}{n}\left(\frac{D_1}{4}\right)^{2/3}(S_1)^{1/2}$$

$$= 2^{(7/6)} \times V_1 = 2^{(7/6)} \text{ m/s.}$$

68. (a)

$$\text{Detention time, } t_d = \frac{\text{Depth of chamber}}{\text{Settling velocity}}$$

Here, Settling velocity $= 0.017$ m/s

$$\therefore \quad t_d = \frac{1.5}{0.017} = 88.24 \text{ sec}$$

$$\text{Length of tank} = V_h \times t_d = 0.3 \times 88.24$$

$$= 26.47 \text{ m} \simeq 27 \text{ m}$$

69. (b)

- Chemicals used in coagulation react with sewage and destroy certain micro-organisms, which are helpful in digestion of sludge.
- It removes the phosphates from sewage and thus may help in eutrophication of river.

70. (d)

In a high rate trickling filter,

$$\text{Recirculation factor} = \frac{1+R}{\left[1+(1-f)R\right]^2}$$

where, R = Recirculation ratio = 1.2 and f = Treatability factor of sewage

$$\therefore \quad f = \frac{1+1.2}{[1+(1-0.8)1.2]^2} = 1.43$$

71. (c)

$$O_2 \text{ demand} = 1.47\, Q(S_o - S) - 1.42\, P_x$$

where, $Q = 0.2 \text{ m}^3/\text{sec} = 0.2 \times 10^3 \times 86400$

$= 17.28 \times 10^6\ l/\text{day}$

$S_o - S = 200 - 20 = 180 \text{ mg}/l$

$P_x = 1.55 \times 10^9 \text{ mg/day}$

$\therefore \quad O_2 \text{ demand} = [1.47 \times 17.28 \times 10^6 \times 180 - 1.42 \times 1.55 \times 10^9] \times 10^{-6}$

$= 2371.29 \text{ kg/day}$

73. (c)

The number of blows required for 30 cm of penetration is taken as the dynamic cone resistance.

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