DETAILED SOLUTIONS

MADE EASY

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 22

Full Syllabus Test 6 : Paper-II

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

DETAILED EXPLANATIONS

1. (b)

The soap bubble has two interfaces.

$$\text{Work done} = \text{Surface tension} \times \text{total surface area}$$

$$= 0.04 \times 4\pi \times \left[\frac{12}{2} \times 10^{-2}\right]^2 \times 2$$

$$= 36.2 \times 10^{-4} \text{ N-m}$$

2. (a)

Considering the pressure at the horizontal plane x-x.

$p_A + 1.5 \times \gamma_{oil} + [2 - 1.5] \times \gamma_{water} + 0.1 \times \gamma_{water} = 0.1\ \gamma_{mercury}$

$p_A + 1.5 \times 0.75 \times 10^3 \times 9.81 + (2 - 1.5) \times 9.81 \times 10^3 + 0.1 \times 9.81 \times 10^3 = 0.1 \times 13.6 \times 10^3 \times 9.81$

$$\Rightarrow \quad p_A = -3.58 \times 10^3 \text{ Pa}$$

$$= -3.58 \text{ kPa}$$

3. (d)

$$\text{Theoretical velocity, } V = \sqrt{2gH}$$

$$= \sqrt{2g \times 2} = 6.264 \text{ m/s}$$

$$\text{Head loss, } h_L = H - \frac{V_a^2}{2g}$$

$$\text{Actual velocity, } V_a = \sqrt{2 \times 9.81 \times (2 - 0.2)}$$

$$= 5.943 \text{ m/s}$$

$$\therefore \quad \text{Coefficient of velocity, } C_v = \frac{V_a}{V} = \frac{5.943}{6.264} = 0.949$$

$$\therefore \quad \text{Coefficient of discharge, } C_d = C_c \cdot C_v$$

$$= 0.63 \times 0.949$$

$$= 0.598 \simeq 0.6$$

4. (c)

For rough turbulent flow:

$$\frac{1}{\sqrt{f}} = 2\log\frac{r_0}{\varepsilon} + 1.74$$

$$\Rightarrow \quad \frac{1}{\sqrt{0.028}} = 2\log\frac{0.15}{\varepsilon} + 1.74$$

$$\Rightarrow \quad 2\log\frac{0.5}{\varepsilon} = \frac{1}{1.67 \times 10^{-1}} - 1.74$$

$$\Rightarrow \quad \log\frac{0.15}{\varepsilon} = 2.12$$

$$\Rightarrow \qquad \varepsilon = \frac{0.15}{10^{2.12}} = 1.14 \times 10^{-3} \text{ m} \simeq 1.14 \text{ mm}$$

5. (b)

$$V_0 = 80 \text{ km/hr} = 22.22 \text{ m/sec.}$$

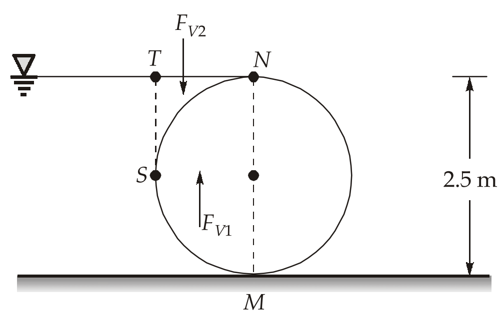
$$\text{Reynold's number, Re} = \frac{V_0 \cdot D}{\nu} = \frac{22.22 \times 0.05}{1.5 \times 10^{-5}} = 7.4 \times 10^4$$

Strouhal number,

$$S = 0.2\left[1 - \frac{20}{\text{Re}}\right]$$

$$= 0.2\left[1 - \frac{20}{7.4 \times 10^4}\right] \simeq 0.2$$

8. (a)



$$\text{Vertical force, } F_v = F_{V1} \text{ on } MS - Fv_2 \text{ on SN}$$

$$F_v = \gamma[\text{Volume of NMST} - \text{Volume of NST}]$$

$$= \gamma\left[\left(\frac{1}{4} \times \frac{\pi}{4} \times 2.5^2\right) + \left(\frac{2.5}{2}\right)^2\right] \times 1 - \gamma\left[\left(\frac{2.5}{2}\right)^2 - \left(\frac{\pi}{4} \times \left(\frac{2.5}{2}\right)^2\right)\right] \times 1$$

$$= \gamma \times \frac{1}{2} \times \frac{\pi}{4} \times (2.5)^2 \times 1$$

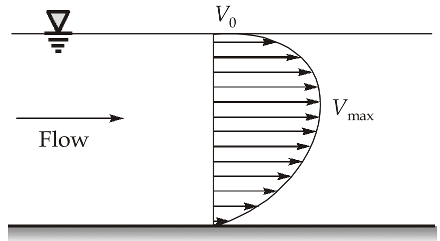
$$= 10 \times \frac{\pi}{8} \times 6.25 \times 1 = 25.54 \text{ kN}$$

9. (d)

$$w_z = \frac{1}{2}\left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]$$

$$= \frac{1}{2}\left[0 - 3xy^2 z\right] = -\frac{3}{2} xy^2 z$$

12. (d)



- In an open channel flow, the maximum velocity does occur at the free surface.
- Due to wind drag on free surface of open channel the flow deaccelerates.

13. (c)

Given:
$$q = 10\,m^3/sec/m$$
$$v_1 = 20\ m/sec.$$

Now,
$$y_1 = \frac{q}{v_1} = \frac{10}{20} = 0.5\ m$$

$$F_{r1} = \frac{v}{\sqrt{g\,y_1}}$$
$$= \frac{20}{\sqrt{9.81 \times 0.5}} \simeq \frac{20}{\sqrt{5}}$$

Now,
$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8F_1^2}\right]$$

$\Rightarrow$
$$\frac{y_2}{0.5} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times \left(\frac{20}{\sqrt{5}}\right)^2}\right]$$

$\Rightarrow$
$$y_2 = 6.08\ m$$

14. (b)

At the maximum contraction, critical depth will occur at the contracted section.

Thus
$$E_1 = E_2 = E_C = 0.96\ m$$
and
$$y_2 = y_{c2}$$
Also,
$$y_C = \frac{2}{3}E_C = \frac{2}{3} \times 0.96 = 0.64\,m$$
But
$$y_{c2} = \left[\frac{q_2^2}{g}\right]^{1/3}$$
$\Rightarrow$
$$0.64 = \left[\frac{q_2^2}{g}\right]^{1/3}$$
$\Rightarrow$
$$q_2 = \sqrt{0.26 \times 10} = 1.6\ m^3/sec/m$$

As, $$q_2 = \frac{Q}{B_{\min}}$$

$\Rightarrow$ $$B_{\min} = \frac{Q}{q_2} = \frac{2.75}{1.6} = 1.7 \text{ m}$$

15. (b)

$$P = \eta_0 \cdot \gamma Q H$$

$\Rightarrow$ $$20{,}000 = 0.85 \times 9.81 \times Q \times 35$$

$\Rightarrow$ $$Q = 68.53 \text{ m}^3/\text{sec}$$

Also, $$Q = \frac{\pi}{4}\left(D_0^2 - D_h^2\right) \times v_{f4}$$

$\Rightarrow$ $$68.53 = \frac{\pi}{4}\left(2.5^2 - 0.85^2\right) \times v_{f1}$$

$\Rightarrow$ $$v_{f1} = 15.8 \text{ m/sec.}$$

16. (a)

$$\text{Specific speed, } (N_s) = \frac{N\sqrt{P}}{H^{5/4}}$$

$$= \frac{300 \times \sqrt{8000}}{[256]^{5/4}} = 26.2 \simeq 26$$

17. (c)

$$(\text{NPSH})_{\text{available}} = H_{\text{atm}} - H_v - H_s - H_{sf}$$

here, $$H_{\text{atm}} = 9.8 \text{ m (abs.)}$$

$$H_v = 0.4 \text{ m (abs.)}$$

$$H_s = 5 \text{ m}$$

$$H_{sf} = 0.6 \text{ m}$$

$\therefore$ $$(\text{NPSH})_{\text{available}} = 9.8 - 0.4 - 5 - 0.6$$

$$= 3.8 \text{ m}$$

19. (d)

$$\frac{x_u}{D} = 1.2$$

$\Rightarrow$ $$x_u = 1.2 \times 500 = 600 \text{ mm}$$

$\Rightarrow$ $$\varepsilon_{cu} = 0.002\left[1 + \frac{3D/7}{x_u - \frac{3D}{7}}\right]$$

$$= 0.002\left[1 + \frac{3 \times \frac{500}{7}}{600 - \frac{3 \times 500}{7}}\right] = 0.00311$$

20. (a)

Reinforcement in the central band = $A_{st,\,short} \times \dfrac{2}{\beta+1}$

Here, $A_{st,\,short} = 5355\ mm^2$

β = Ratio of long side to short side

$= \dfrac{3.4}{2.5} = 1.36$

$\therefore$ Reinforcement in central band $= \dfrac{5355\times 2}{1.36+1} = 4538\ mm^2$

21. (c)

For actual depth of neutral axis,

$$C = T$$

$$\Rightarrow \quad C_1 + C_2 = T$$

$$\Rightarrow \quad 0.36 f_{ck}.\ b.\ x_u + [f_{sc} - 0.45 f_{ck}]A_{sc} = 0.87 f_y \times A_{st}$$

Check for strain, $\in_{sc} = 0.0035\left[\dfrac{x_{u\,lim} - d_c}{x_{u\,lim}}\right]$

$x_{u,\,lim} = 0.53 \times d$ for Fe250

$= 0.53 \times 400 = 212$ mm

$$\therefore \quad \in_{sc} = 0.0035\left[\frac{212-50}{212}\right]$$

$= 0.002675 > 0.001875$

$\therefore \quad f_{sc} = 0.87 \times 250 = 217.5\ N/mm^2$

$$0.36\times 20\times 250\times x_u + [217.5 - 0.45\times 20]\times 4\times\frac{\pi}{4}\times 18^2 = 0.87\times 250\times 4\times\frac{\pi}{4}\times 25^2$$

$$\Rightarrow \quad x_u = 119.35\ mm$$

22. (a)

Cracks are inclined at 45° where the bending stresses are zero.

23. (d)

For Fe415 grade steel and continuous slab,

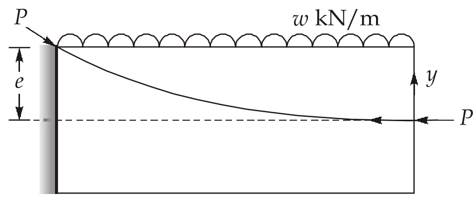
$$\frac{\text{Short span}}{\text{Overall depth}} = 32$$

$$\Rightarrow \quad \frac{3000}{32} = D$$

$$\Rightarrow \quad D = 93.75\ mm$$

$\simeq 95$ mm

24. (c)



As the bending moment diagram due to cantilever will be parabolic hence we will choose the cable profile as parabolic only.

The eccentricity provided by the profile should produce moment which is equal but opposite to the external moment.

$$\therefore \quad Py = \frac{wx^2}{2}$$

$$\Rightarrow \quad y = \frac{wx^2}{2P} \quad \text{...(1)}$$

At $x = l$,

$$e = \frac{w \times l^2}{2P} \quad \text{...(2)}$$

From (1) and (2)

$$\frac{y}{e} = \frac{x^2}{l^2}$$

$$\Rightarrow \quad y = \frac{ex^2}{l^2}$$

25. (a)

Given:

$$p = 1000 \text{ N/mm}^2$$
$$A = 565 \text{ mm}^2$$
$$e = 300 - 200 = 100 \text{ mm}$$
$$\therefore \quad P = \text{p.A}$$
$$= 1000 \times 565 = 565 \text{ kN}$$

Now, let 'M' be the bending moment required so that the tension at the soffit is just avoided.

$$\therefore \quad \frac{P}{A} + \frac{P.e}{Z} - \frac{M}{Z} = 0$$

$$\frac{565 \times 10^3}{300 \times 600} + \frac{565 \times 10^3 \times 100}{\frac{300 \times 600^2}{6}} - \left[\frac{M}{\left(\frac{300 \times 600^2}{6}\right)}\right] = 0$$

$$\Rightarrow \quad 3.14 + 3.14 - \frac{M}{18 \times 10^6} = 0$$

$$\Rightarrow \quad M = 113.04 \times 10^6 \text{ N-mm}$$
$$= 113.04 \text{ kN-m}$$

26. **(d)**

In general, the slope of the stair should never exceed 40° and must not be flatter than 25°.

27. **(c)**

As per IS : 3370 (Part-1): 2009:

Concrete	Minimum cement content kg/m^3	Maxiimum free water cement ratio	Minimum grade of concrete
1. Plain Concrete	250	0.50	M20
2. Reinforced concrete	320	0.45	M30
3. Prestressed concrete	360	0.40	M40

28. **(b)**

Long term modulus of elasticity of concrete,

$$E = \frac{E_c}{1+\theta}$$

Here, $E_c = 5000\sqrt{f_{ck}}$

$\theta = 1.6$ at an age of 28 days

$$\therefore \quad E = \frac{5000 \times \sqrt{25}}{1+1.6}$$

$$= 9615.4 \text{MPa}$$

29. **(b)**

Refer IS 1343 – 2012, Clause 13.2.4.1

The transfer of the prestress shall be carried out gradually so as to avoid large differences of tension between wires in a tendon, service electricities of prestressing force and the sudden application of stress to the concrete.

31. **(d)**

$$\text{NIR} = C_u - P_{\text{eff.}}$$

$$C_u = 0.5 \times \frac{\gamma_d}{\gamma_w} \times d \times (F.C. - PWP)$$

$$\Rightarrow \quad C_u = 0.5 \times \frac{16}{10} \times 1000 \times [0.25 - 0.15] = 80 \text{ mm}$$

Effective rainfall = 40 mm

$$\therefore \quad \text{NIR} = 80 - 40 = 40 \text{ mm}$$

32. **(a)**

$$\text{Hydraulic mean depth, } R = \frac{5}{2} \times \frac{v^2}{f}$$

$$= \frac{5}{2} \times \frac{0.8^2}{1.1} = 1.45 \text{ m}$$

33. (b)

$$\text{Sensitivity, } S = \frac{dq/q}{dy/y}$$

Given, $S = 0.5$

$$\therefore \quad \frac{dq}{q} = \frac{dy}{y} \times S$$

$$= 0.4 \times 50 = 20\%$$

34. (c)

For elementary profile of gravity dam, $B = \frac{H}{\sqrt{G-C}}$

When Uplift is ignored, $C = 0$

$$\therefore \quad B = \frac{H}{\sqrt{G}}$$

$$\Rightarrow \quad H = 36 \times \sqrt{2.56} = 57.6\,\text{m}$$

38. (d)

Sound absorbing mortar: Portland cement with sand from light weight porous material such as cinders, pumice etc.

Fire shielding Mortar: Aluminous cement with finely powdered fire brick in proportion of 1 : 2.

39. (c)

Elongation index on an aggregate is defined by weight of particles present in it whose greatest dimension is greater than nine-fifth of their mean dimension.

41. (a)

1 m^3 of freshly mixed concrete is equivalent to 1.54 m^3 of dry volume of concrete.

Summation of proportions = 1 + 1.5 + 3 = 5.5

$$\therefore \quad \text{Volume of sand} = \frac{1.5}{5.5} \times 1.54 = 0.42\ m^3$$

43. (b)

If nominal maximum size of aggregate is 20 mm then maximum water content is 186 kg out it should be reduced by 25 kg as aggregates are rounded.

For each additional 25 mm slump, water content is increased by 3%.

44. (a)

Fly ash in concrete prevents it from thermal cracking.

45. (b)

Sand type	Fineness modulus
Coarse	2.2 - 2.6
Medium	2.6 - 2.9
Fine	2.9 - 3.2

46. (d)

Potash-lime glass, also known as hard glass, is used in manufacture of glass articles which have to withstand high temperature such as combustion tubes etc.

49. (d)

Sodium nitrate is a retarder.

50. (c)

Parallax in aerial photographs is an error due to movement of camera and ground relief.

52. (a)

Correction for absolute length of tape = 29.95 – 30

= – 0.05 m

Correction for temperature = $-L\alpha\Delta T$

= $30 \times 5 \times 10^{-6} \times [35° - 20°]$

= – 0.0025 m

∴ Total correction = – (0.05 + 0.0025) = – 0.0525 m

Total correction for the measured line = $\frac{-8000}{30} \times 0.0525$

= – 14 m

53. (d)

- The length of the long chord of a simple circular curve is not twice the apex distance.
- A compound curve has two or more simple circular curves of different radii.

54. (c)

$$\text{True difference in elevations} = \frac{(h_B - h_A) + (h_B' - h_A')}{2}$$

$$= \frac{(1.95 - 1.35) + (2.01 - 1.54)}{2}$$

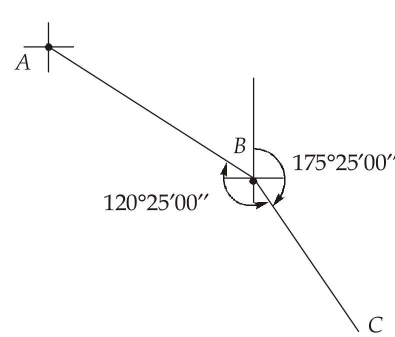
$$= \frac{1.07}{2} = 0.535 \text{ m}$$

∴ R.L of B = 130 – 0.535

= 129.465 m

55. (a)

Given,

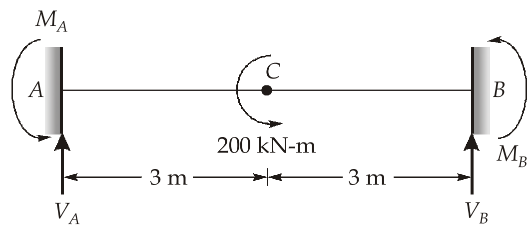


From the figure shown above

$$\text{Back bearing of line } AB = 175°\ 25'\ 00'' + 120°\ 25'\ 00'' = 295°\ 50'\ 00''$$

$$\therefore \quad \text{Bearing of line } AB = 295°\ 50'\ 00'' - 180°\ 00'\ 00'' = 115°\ 50'\ 00''$$

56. (b)



$$\text{Due to moment at } C,\ M_A = M_B = \frac{-200}{4} = -50 \text{ kN-m}$$

Now,

$$\Sigma M_B = 0$$

$$\Rightarrow \quad V_A \times 6 + M_A + M_B - 200 = 0$$

$$\Rightarrow \quad V_A \times 6 - 50 - 50 - 200 = 0$$

$$\Rightarrow \quad V_A = \frac{300}{6} \text{kN} = 50 \text{ kN (Upwards)}$$

57. (a)

$$M_{FAB} = \frac{-10 \times 4}{8} = -5 \text{ kN-m}$$

$$M_{FBA} = \frac{10 \times 4}{8} = 5 \text{ kN-m}$$

$$M_{FBC} = M_{FCB} = 0$$

$$M_{BA} = M_{FBA} + \frac{2EI}{L}(2\theta_B) \qquad [\because \theta_A = 0]$$

$$= 5 + \frac{4EI\theta_B}{4}$$

$$= 5 + EI\theta_B$$

$$M_{BC} = M_{FBC} + \frac{2EI}{L}(2\theta_B) \qquad [\because \theta_C = 0]$$

$$= \frac{2EI}{4}(2\theta_B)$$

$$= EI\theta_B$$

Now,

$$M_{BA} + M_{BC} = 0$$

$$\Rightarrow \quad 5 + EI\theta_B + EI\theta_B = 0$$

$$\Rightarrow \quad \theta_B = \frac{-5}{2EI} = \frac{5}{2EI} \text{ (Anticlockwise)}$$

58. (d)

Degree of static indeterminacy, $D_s = 3m + r_e - 3_j - r_r$

where m is number of members i.e. 9

r_e is number of external reactions i.e. 5 i.e. (3 + 2)

j is number of joints i.e. 8.

r_r is number of reactions released $= \Sigma(\dot{m} - 1)$

$= (3 - 1) + (2 - 1) = 3$

So, $D_s = 3 \times 9 + 5 - 3 \times 8 - 3$

$= 5$

60. (c)

$$\text{Curved length of cable, } L = l + \frac{8}{3}\frac{h^2}{l}$$

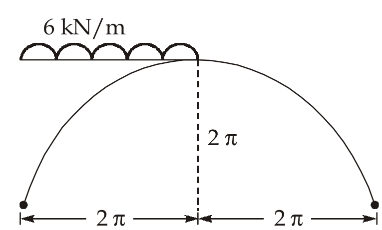
$$= 20 + \frac{8}{3} \times \frac{3^2}{20} = 21.2 \text{ m}$$

61. (c)

Material should be linearly elastic.

63. (a)

If UDL covers whole of the span, then horizontal thrust, $H = \frac{4}{3}\frac{wR}{\pi}$

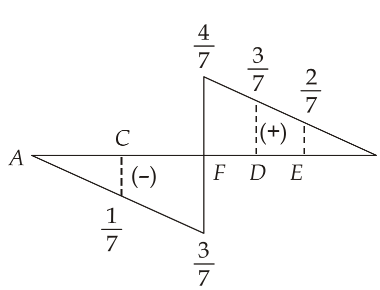


$$\text{For this case, } H = \frac{2}{3}\frac{wR}{\pi}$$

$$= \frac{2}{3} \times \frac{6 \times 2\pi}{\pi} = 8 \text{ kN}$$

64. (d)

ILD for shear force at F is shown below.



$$\text{Now, shear force at } F = 8 \times \frac{1}{2} \times \left[\left(\frac{-1}{7} + \left(\frac{-3}{7}\right)\right) \times 2\right] + 8 \times \frac{1}{2}\left[\frac{4}{7} + \frac{3}{7}\right] \times 1 + 90 \times \frac{2}{7} + 8 \times \frac{1}{2} \times 2 \times \frac{2}{7}$$

$$= -8\times\frac{4}{7}+8\times\frac{1}{2}+\frac{180}{7}+\frac{16}{7}$$

$$= \frac{-32}{7}+4+\frac{196}{7} = \frac{192}{7}\text{ kN}$$

Alternatively,

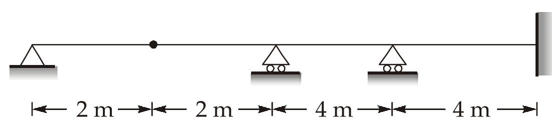
$$\Sigma_{MB} = 0$$

$\Rightarrow$ $$V_A(7) = 8\times 3\times 4.5 + 90\times 2 + 8\times 2$$

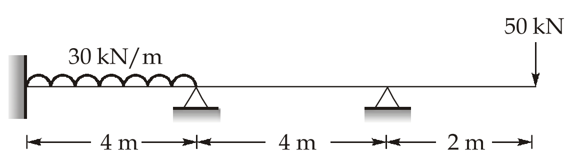
$\Rightarrow$ $$V_A = \frac{304}{7}$$

$\Rightarrow$ $$SF \text{ at } F = \frac{304}{7} - 8\times 2 = \frac{192}{7}\text{ kN}$$

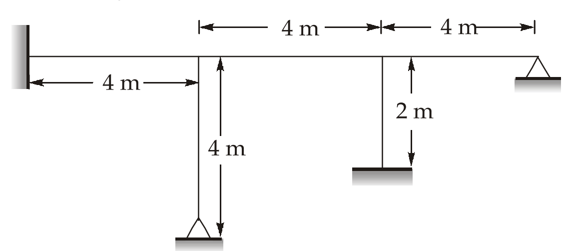
65. (d)



$$D_s = 3\text{ m} + r_e - 3j - r_r$$
$$= 3\times 4 + 7 - 3\times 5 - 1 = 3$$



$$D_s = 4 - 2 = 2$$ [Vertical loading only]



$$D_s = 3\times 5 + 10 - 3\times 6 = 7$$

66. (d)

Given:

$$C_p = 0.5$$
$$A = 1000\text{ ha} = 10\text{ km}^2$$
$$t_p = 120\text{ min} = 2\text{ hr}$$

Peak discharge, $$Q_p = \frac{2.78\,C_p A}{t_p}$$

$$= \frac{2.78\times 0.5\times 10}{2} = 6.95\text{ m}^3/\text{sec}$$

67. (b)

No object should be nearer to the instrument than 30 m twice the height of the obstruction.

68. (a)

$$\text{Volume of runoff} = \text{Area of DRH}$$

$$\Rightarrow \quad \pi r^2 \times \left(\frac{\theta}{360^\circ}\right) \times \Delta = \frac{1}{2} \times (12 \times 3600) \times Q_p$$

$$\Rightarrow \quad \pi \times 3000^2 \times \frac{30^\circ}{360^\circ} \times \frac{3}{100} = \frac{1}{2} \times 12 \times 3600 \times Q_p$$

$$\Rightarrow \quad Q_p = 3.27 \text{ m}^3/\text{sec}$$

69. (c)

As per Weibull's formula,

$$P = \frac{m}{N+1}$$

Here, $m = 7$

$N = 12$

$$\therefore \quad P = \frac{7}{12+1} = \frac{7}{13}$$

Now, $P = \dfrac{1}{T}$

$$\Rightarrow \quad T = \frac{1}{p} = \frac{13}{7} \text{ years}$$

70. (d)

$$W(u) = \int_0^\infty \frac{e^{-u}}{u} du$$

$$= -0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} + \ldots$$

71. (c)

$$\gamma_{\text{bulk}} = \gamma_{\text{dry}} \times (1 + w)$$

$$\Rightarrow \quad \gamma_{\text{bulk}} = \frac{G \cdot \gamma_w}{1+e} \times (1+w)$$

$$\Rightarrow \quad 18 = \frac{2.65 \times 10}{1+e} \times (1 + 0.12)$$

$$\Rightarrow \quad e = 0.65$$

Now, $n = \dfrac{e}{1+e} = \dfrac{0.65}{1+0.65} = 0.39$

Now, seepage velocity, $V_s = \frac{V_{avg.}}{n}$

$$= \frac{V_{avg.}}{0.39} = 2.56\,V_{avg.} \simeq 2.6\ V_{avg.}$$

72. (b)

In the given soil profile, flow is in upward direction, which leads to decrease in effective stress.

$$\bar{\sigma} = \gamma' z - iz \cdot \gamma_w$$

$$i = \frac{\Delta h}{L} = \frac{2}{4} = 0.5$$

$$z = 3 \text{ m}$$

$\therefore$ $\gamma_w = 10 \text{ kN/m}^3$

$\therefore$ $\bar{\sigma} = (21 - 10) \times 3 - 0.5 \times 3 \times 10$

$$= 11 \times 3 - 0.5 \times 30 = 33 - 15 = 18 \text{ kN/m}^2$$

74. (a)

There will be no change in $\frac{N_f}{N_D}$ ratio, it is only the pattern that will get changed.

75. (d)

We know that, factor of safety in cohesive soil is,

$$F = \frac{C + \gamma_{sub} z \cos^2\beta \tan\phi}{\gamma_{sat} H \sin\beta \cdot \cos\beta}$$

Here, $\beta = 10°$ and $\phi = 25°$

$$\gamma_{sub} = \gamma_{sat} - \gamma_w = 20 - 10 = 10 \text{ kN/m}^3$$

$$c = 20 \text{ kN/m}^2$$

$$z = 5 \text{ m}$$

$\therefore$ $F = \frac{20 + 10 \times 5 \times \cos^2 10° \times \tan 25°}{20 \times 5 \times \sin 10° \times \cos 10°}$

$$= \frac{20 + 10 \times 5 \times 0.98^2 \times 0.47}{20 \times 5 \times 0.17 \times 0.98} = 2.56 \simeq 2.6$$

76. (b)

$$Q_{up} = 9CA_b + \alpha CA_s$$

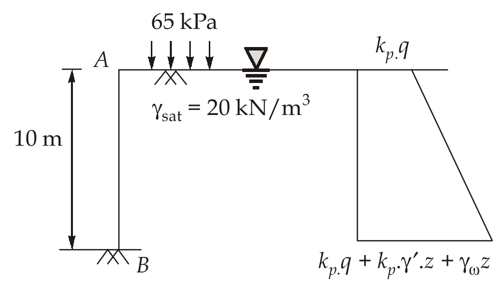
$\Rightarrow$ $Q_{up} = 9C \cdot \frac{\pi}{4} D^2 + \alpha \cdot C \cdot \pi DL$

$\Rightarrow$ $350\pi = 9C \cdot \frac{\pi}{4} D^2 + \alpha\, C\, \pi DL$

$\Rightarrow$ $350 = 9 \times 70 \times \frac{1}{4} \times 1^2 + 0.4 \times 70 \times 1 \times L$

$\Rightarrow$ $L = \frac{350 - \frac{9 \times 70}{4}}{0.4 \times 70} = 6.875 \text{ m}$

77. (c)



$$\phi = 30°$$

$$k_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = 3$$

$\therefore$

$$(p_p)_A = k_p.q = 3 \times 65 = 195 \text{ kN/m}^2$$

$$(p_p)_B = k_p.q + k_p.\gamma' z + \gamma_w z$$

$$= 195 + 3 \times [20 - 10] \times 10 + 10 \times 10 = 595 \text{ kN/m}^2$$

$$\text{Passive earth pressure on wall} = \left[\frac{195+595}{2}\right] \times 10 = 3950 \text{ kN/m}$$

78. (a)

- When soil water table is between ground level and foundation base, it will effect the bearing capacity.
- Terzaghi's theory is applicable only for general shear failure but for local shear failure, cohesion and friction angle values has to be modified.

81. (c)

$\therefore$ Plate is circular and footing is square.

$\therefore$

$$\frac{q_f}{q_p} = \frac{0.4 \times B_f}{0.3 \times B_P}$$

$$= \frac{4}{3} \times \frac{1.5}{0.3} = \frac{20}{3}$$

84. (c)

Minimum CSI prescribed in Indian Railways for wooden sleepers at bridge is 1455.

85. (b)

The direction of wind opposite to direction of landing and take-off provides greater lift. Thus it rises early and in a shorter length of runway.

86. (c)

$$\text{Weighted average speed, } V = \frac{n_1V_1 + n_2V_2 + n_3V_3}{n_1 + n_2 + n_3}$$

$$= \frac{15(60) + 20(40) + 5(80)}{15 + 20 + 5} = 52.5 \text{ kmph}$$

Equilibrium superelevation, $e = \dfrac{GV^2}{127R}$

$= \dfrac{1.75 \times 10^3 \times 52.5^2}{127 \times 875}$ mm $= 43.4$ mm $= 4.34$ cm

87. (d)

In stub switch, no separate tongue rail is provided. It is obsolete now. Split switch is the modern type which consists of stock rail and tongue rail.

88. (b)

Dissolved oxygen of sea water is about 20% less than that in stream water.

90. (d)

Maximum hourly demand of maximum day = $1.5 \times 1.8q$

[where q is average daily water demand]

$= 2.7q$

$= 2.7 \times 300 \times 3 \times 10^5 \times 10^{-6}$ MLD

$= 243$ MLD

91. (a)

Water entering the slow sand filters should not be treated by coagulants because it considerably affects the economical working of the filters.

93. (a)

Water treated per day = $30{,}000 \text{ m}^3/\text{day}$

$= 30 \times 10^6$ lt/day

Chlorine consumed per day = 8 kg = 8×10^6 mg/day

Chlorine used per litre of water = $\dfrac{8 \times 10^6}{30 \times 10^6} = 0.27$ mg/l

Chlorine demand of water = $0.27 - 0.15$

$= 0.12$ mg/l

94. (c)

Volatile liquids such as humic acids and phenols can be removed by aeration.

96. (a)

BOD entering into aeration tank = $Q_o S_o$

$= 0.2 \times 10^3 \times 24 \times 3600 \times 100 \times 10^{-6}$ kg/d

$= 1728$ kg/d

BOD leaving from the aeration tank = $Q_o S$

$= 0.2 \times 10^3 \times 24 \times 3600 \times 20 \times 10^{-6}$ kg/d

$= 345.6$ kg/d

$\therefore$ BOD removed in aeration tank = (BOD entering – BOD leaving)

$= 1728 - 345.6 = 1382.4$ kg/d

97. (b)

Biomass obtained in sludge from SST

$$= 0.35 \times 1382.4$$

$$= 483.84 \text{ kg/d} \simeq 483.8 \text{ kg/d}$$

98. (c)

$$\frac{F}{M} = \frac{Q_0 S_0}{Vx}$$

$$= \frac{0.2 \times 24 \times 3600 \times 100}{3000 \times 3000} = 0.192 \text{ d}^{-1}$$

102. (c)

$$\text{Deviation angle, } N = \left| -\frac{1}{20} - \frac{1}{40} \right| = \frac{3}{40}$$

Now, distance of lowest point from first tangent point is:

$$x = L\sqrt{\frac{n_1}{2N}}$$

$$= 190 \times \sqrt{\frac{1}{20} \times \frac{40}{2 \times 3}}$$

$$= 190 \times \frac{1}{1.73} = 109.83 \text{ m}$$

103. (d)

- Rate of change of centrifugal acceleration should be constant.
- Radius of transition curve decreases from infinity to radius of circular curve.
- Length of curve is inversely proportional to radius of circular curve.

104. (b)

As per Greenshield's model

$$\text{Traffic volume, } q = k \times u$$

$$= k \times U_{sf}\left(1 - \frac{k}{k_j}\right)$$

$$= U_{sf}\left(k - \frac{k^2}{k_j}\right)$$

At $k = 50$ veh/km,

$$q = 80 \times \left(50 - \frac{50^2}{125}\right)$$

$$= 80 \times (50 - 20) = 2400 \text{ veh/hr}$$

105. **(c)**

Surface layer is infinite in horizontal direction and finite in vertical direction.

107. **(b)**

As we know, joint filler is assumed to get compressed upto 50% of its original thickness.

So, $\frac{\delta}{2} = L_e \alpha \Delta t$ where L_e is spacing between the joints.

$$\Rightarrow \left(\frac{2.4 \times 10^{-2}}{2}\right) = L_e \times 10 \times 10^{-6} \times 48°$$

$$\Rightarrow L_e = \frac{1.2 \times 10^{-2}}{10^{-5} \times 48} = 25\,\text{m}$$

108. **(c)**

$$\text{Percentage air voids, } V_v = \left(\frac{G_t - G_m}{G_t}\right) \times 100$$

$$= \frac{2.44 - 2.32}{2.44} \times 100 = 4.92\%$$

109. **(c)**

$$\text{True stress, } \sigma_t = \sigma_0 (1 + \varepsilon)$$

$$= \frac{150 \times 10^3}{500}\left(1 + \frac{0.25}{250}\right)$$

$$= 300.3\ \text{N/mm}^2$$

110. **(a)**

Consider a strip of length dx at distance x from left end.

Now, expansion of strip, $d\Delta = dx \alpha \Delta T$

$$= \alpha \Delta T_B \left(\frac{x}{L}\right)^m dx$$

So, free expansion of bar AB, $\Delta = \int_0^L d\Delta$

$$= \int_0^L \alpha \Delta T_B \left(\frac{x}{L}\right)^m dx$$

$$= \frac{\alpha \Delta T_B \left[(x)^{m+1}\right]_0^L}{L^m (m+1)} = \frac{L \alpha \Delta T_B}{m+1}$$

Now, as the bar is clamped at both the ends, and thus net elongation = 0

$$\Rightarrow \quad \frac{L\alpha\Delta T_B}{m+1} - \frac{\sigma_C L}{E} = 0$$

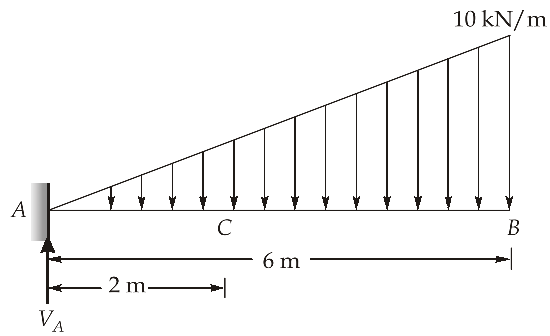
$$\Rightarrow \quad \sigma_C = \frac{L\alpha\Delta T_B}{m+1}$$

111. (b)

$$\Sigma F_y = 0$$

$$\Rightarrow \quad V_A - \frac{1}{2}\times 6\times 10 = 0$$

$$\Rightarrow \quad V_A = 30\text{ kN}$$



Now,
$$(\text{S.F})_C = V_A - \frac{1}{2}\times 2\times\left(\frac{2}{6}\right)\times 10$$

$$= 30 - \frac{10}{3} = \frac{80}{3}\text{ kN}$$

112. (a)

As the torque and outside radius in both the shafts are same and so maximum shear stress is inversely proportional to polar moment of inertia.

So,
$$\frac{\tau_{\text{hollow}}}{\tau_{\text{solid}}} = \frac{(I_p)_{\text{solid}}}{(I_p)_{\text{hollow}}}$$

$$= \frac{\dfrac{\pi R^4}{2}}{\dfrac{\pi}{2}\left(R^4 - (0.5R)^4\right)}$$

$$= \frac{1}{1-0.5^4}$$

$$= \frac{1}{1-\dfrac{1}{16}} = \frac{16}{15}$$

113. (c)

Major principal stresses in a thin cylinder are hoop stresses.

Now, $$\sigma_h = \frac{pD}{2t}$$

where
$$P = \rho g h = 1000 \times 10 \times 200 = 2 \times 10^6 \text{ Pa}$$

$\therefore$
$$\sigma_h = \frac{2 \times 10^6 \times 1}{2 \times (50 \times 10^{-3})} = 20 \times 10^6 \text{ Pa} = 20 \text{ MPa}$$

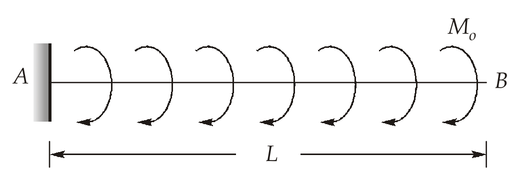
114. (c)

Maximum eccentricity, $$e \le \frac{D_0^2 + D_i^2}{8D_0}$$

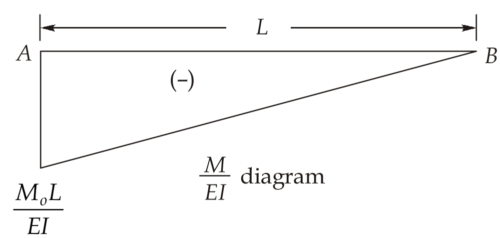
$$\Rightarrow \quad e \le \frac{50^2 + 30^2}{8 \times 50}$$

$$\Rightarrow \quad e \le 8.5 \text{ mm}$$

115. (b)



$\frac{M}{EI}$ diagram of beam is shown in figure.

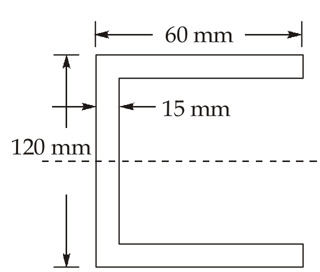


Now, using area-moment method,

$$\theta_B - \theta_A = \frac{-1}{2} \times L \times \frac{M_oL}{EI} = -\frac{M_oL^2}{2EI}$$

117. (a)

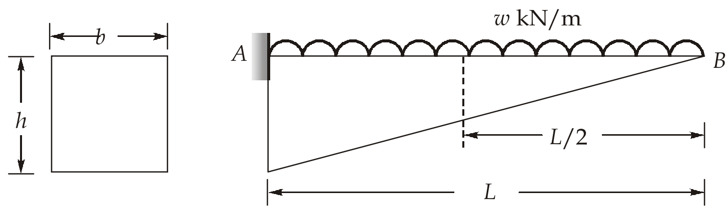
$$\tau_{mid} = \frac{VA\bar{y}}{Ib}$$



where
$$A\bar{y} = 60 \times 15 \times (60 - 7.5) + 45 \times 15 \times 22.5 = 47250 + 15187.5 = 62437.5 \text{ mm}^3$$

So, $$\tau_{mid} = \frac{59 \times 10^3 \times 62437.5}{59 \times 10^5 \times 15}$$
$$= 41.625 \text{ N/mm}^2 \simeq 41.6 \text{ N/mm}^2$$

118. (c)



At support

$$\sigma = \frac{M}{Z} = \frac{wL^2 \times 6}{2 \times bh^2} = \frac{3wL^2}{bh^2}$$

At midspan

$$\sigma_{mid} = \frac{M_{mid}}{Z_{mid}} = \frac{w \times \left(\frac{L}{2}\right)\frac{1}{2}\left(\frac{L}{2}\right) \times 6}{b \times h_x^2} = \frac{3wL^2}{4bh_x^2}$$

Now, $$\sigma = \sigma_{mid}$$

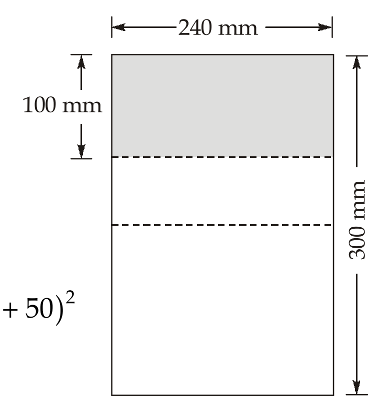
$\Rightarrow$ $$\frac{3wL^2}{bh^2} = \frac{3wL^2}{4bh_x^2}$$

$\Rightarrow$ $$h_x^2 = \frac{h^2}{4}$$

$\Rightarrow$ $$h_x = \frac{h}{2} = \frac{300}{2} = 150 \text{ mm}$$

119. (c)

Moment resisted by shaded portion,



$$M_{1/3} = \frac{\sigma_{max}}{y_{max}} \times I_{Area}$$
$$= \frac{M}{I} \times I_{Area}$$

where $$I_{Area} = \frac{240 \times 100^3}{12} + 240 \times 100 \times (50 + 50)^2$$
$$= (20 + 240) \times 10^6$$
$$= 260 \times 10^6 \text{ mm}^4$$

$$I = \frac{240 \times 300^3}{12} = 540 \times 10^6 \text{ mm}^4$$

So, $$M_{1/3} = \frac{150 \times 260 \times 10^6}{540 \times 10^6} = 72.22 \text{ kN-m}$$

120. (a)

$$\Sigma M_C = 0 \quad \text{[Internal hinge]}$$

$$\Rightarrow \quad -V_B \times 3 + 30 \times 2 = 0$$

$$\Rightarrow \quad V_B = \frac{30 \times 2}{3} = 20\,\text{kN}$$

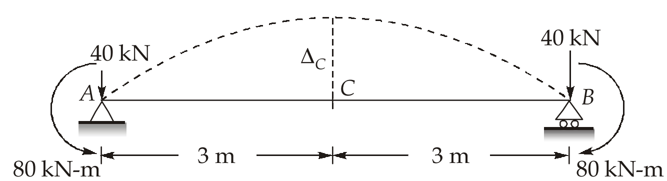
Now, $\Sigma F_y = 0$

$$\Rightarrow \quad V_A + V_B - 10 \times 3 - 30 = 0$$

$$\Rightarrow \quad V_A = 40\text{ kN}$$

Here 'EI' is flexural rigidity of beam in kN-m.

121. (c)

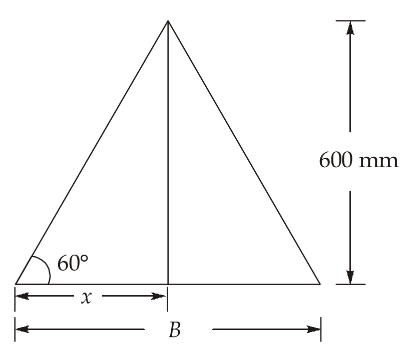


Vertical deflection at C, $\Delta_C = \dfrac{2 \times Ml^2}{16EI}$

where $M = 80$ kN-m

So, $\Delta_C = \dfrac{2 \times 80 \times 6^2}{16EI} = \dfrac{360}{EI}(\uparrow)$

122. (a)



$$\Rightarrow \quad x = \frac{600}{\tan 60°}$$

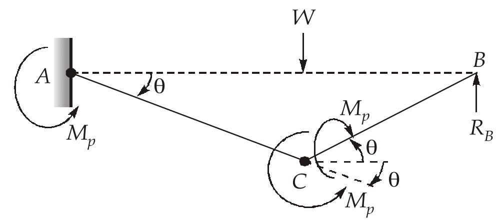
$$\therefore \quad B = 2x = \frac{2 \times 600}{\tan 60°} = 692.82\text{ mm}$$

$$\text{Area of triangle} = \frac{692.82 \times 600}{2} = 207846\,\text{mm}^2$$

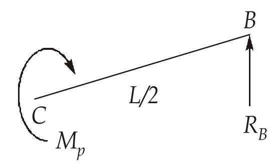
Since D is neutral axis distance in the plastic moment condition and thus, area of shaded region will be equal to half the area of triangle.

$\therefore$ Area of shaded region $= 103923\text{ mm}^2$

123. (a)



Consider *FBD* of portion *BC*,



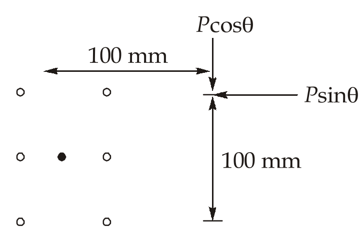
$$\Sigma M_C = 0$$

$$\Rightarrow \quad -R_B \times \frac{L}{2} + M_p = 0$$

$$\Rightarrow \quad R_B = \frac{2M_p}{L}$$

126. (d)

Moment about C.G. of the bolt group.



$$\Rightarrow \quad M = P\cos 45° \times 100 - P\sin 45° \times 100 = 0$$

∴ It is a moment free connection

∴ All the bolts are critical.

127. (d)

In case of angle members, lug angles and their connection to the gussets should be capable of developing strength not less than 20% in excess of the force in the outstanding leg of the angle. The attachment of the lug angle to the angle member should be capable of developing 40% in excess of that force.

128. (b)

$$\text{Minimum width of lacing member} = 3 \times \text{nominal dia. of bolt}$$
$$= 3 \times 20 = 60 \text{ mm}$$

$$\text{Minimum thickness for single lacing system} = \frac{l_{eff}}{40}$$

$$= \frac{240}{40} = 6 \text{ mm}$$

131. (a)

$$A = 450 \times 400 = 18 \times 10^4 \text{ mm}^2$$

$$Z_{xx} = \frac{1}{6} \times 450 \times 400^2 = 12 \times 10^6 \text{ mm}^3$$

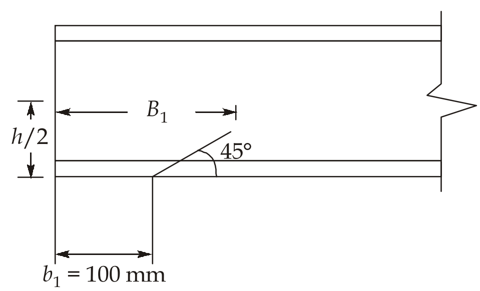
$$Z_{yy} = \frac{1}{6} \times 400 \times 450^2 = 13.5 \times 10^6 \text{ mm}^2$$

Maximum bearing stress,

$$p_{max} = \frac{200 \times 10^3}{18 \times 10^4} + \frac{15 \times 10^6}{12 \times 10^6} \times \frac{10 \times 10^6}{13.5 \times 10^6}$$

$$= 1.11 + 1.25 + 0.74 = 3.1 \text{ N/mm}^2$$

132. (c)



$$B_1 = b_1 + \frac{h}{2} = 100 + \frac{350}{2} = 275 \text{ mm}$$

$$\text{Web buckling strength} = B_1 \times t_w \times f_{cd}$$

$$\lambda = \frac{0.7 d_1}{t_w / \sqrt{12}} \simeq 2.5 \frac{d_1}{t_w}$$

$$d_1 = 350 - 2 \times (11.4 + 16) \simeq 295.2 \text{ mm}$$

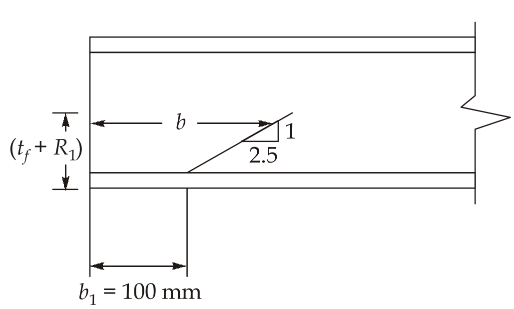
$$\Rightarrow \quad \lambda = \frac{2.5 \times 295.2}{7.4} = 99.729$$

$$\Rightarrow \quad \lambda \simeq 100$$

$$\therefore \quad f_{cd} = 107 \text{ N/mm}^2$$

$$\therefore \quad f_{wb} = \frac{275 \times 7.4 \times 107}{1000} \text{ kN} = 217.745 \text{ kN} \simeq 218 \text{ kN}$$

133. (a)



$$\text{Bearing length, } b = b_1 + 2.5(t_f + R_1)$$
$$= 100 + 2.5(11.4 + 16) = 168.5 \text{ mm}$$
$$F_w = \frac{F_y}{\gamma_{mo}} \times b \times t_w$$
$$= \frac{250}{1.1} \times 168.5 \times 7.4 \times 10^{-3} \text{ kN}$$
$$\simeq 283 \text{ kN}$$

134. (b)

Bar chart does not facilitate the work of controlling, monitoring and updating of the project.

136. (a)

The probability factor, z is given as

$$Z = \frac{T_S - T_E}{\sigma}$$

where, σ is standard deviation, $\sigma = \sqrt{9}$

$$\sigma = 3 \text{ weeks}$$

Now, $T_s = 1.647 \times 3 + 50$

$$= 54.941 \text{ weeks}$$

138. (a)

Critical path is timewise the longest path.

Path 1

A - B - D - F - H - J = 5 + 15 + 20 + 10 + 20 + 10 = 80 days

Path 2

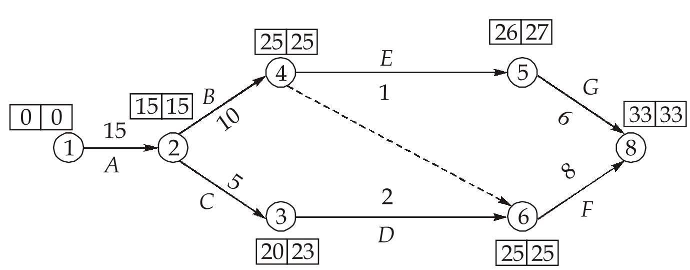
A - C - F - H - J = 5 + 25 + 10 + 20 + 10 = 70 days

Path 3

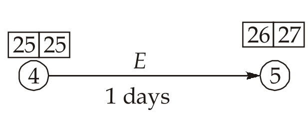
A - C - E - G - I - J = 5 + 25 + 20 + 10 + 5 + 10 = 75 days

Hence, critical path is A - B - D - F - H - J.

139. (a)



(Duration in days)



Event 4 : EST = 25 days
LST = 27 – 1 days
= 26 days

Event 5 : EFT = 25 + 1 = 26 days
LFT = 27 days

$$\text{Total float, } (F_T) = \text{LST} - \text{EST} = 26 - 25 = 1 \text{ day}$$

142. (a)

$$\text{Output} = \frac{\text{Average speed} \times \text{Effective width}}{5}$$

$$= \frac{(2\times1000)\times(1.8)}{5} \text{m}^2/\text{h} = 720 \text{ m}^2/\text{hr}$$

$$= \frac{720\,\text{m}^2}{60\times60} = 0.2 \text{ m}^2/\text{sec}$$

144. (c)

In Bukinghm's method, when the number of independent variables exceed three, the exponents of non-repeating variables are expressed as exponents of repeating variables.

145. (a)

The spacing of stirrups shall be such that it intercepts the crack and also no crack shall remain unreinforced. To ensure this, the spacing of vertical stirrups is limited to 0.75d.

146. (d)

A drainage gallery reduces the uplift pressure at all levels below the gallery i.e. upstream as well as downstream.

147. (a)

Hydration of C_3S produces $Ca(OH)_2$ which is soluble in water and leaches out making concrete porous in hydrolytic structure.

150. (b)

In case of pure shear

$$\sigma_1 = \tau \text{ and } \sigma_2 = -\tau$$

So,
$$\frac{\sigma_1}{\sigma_2} = \frac{\tau}{-\tau} = -1$$

Also,
$$\varepsilon_1 = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E}$$

$$= \frac{\tau}{E} - \frac{\mu(-\tau)}{E} = \frac{\tau}{E}(1+\mu)$$

$$\varepsilon_2 = \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} = \frac{-\tau}{E}\frac{-\mu(\tau)}{E} = \frac{-\tau}{E}(1+\mu)$$

So,
$$\frac{\varepsilon_1}{\varepsilon_2} = -1$$

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