DETAILED SOLUTIONS

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ESE 2020 : 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 Engg.-2+ Environmental Engg.-2

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

DETAILED EXPLANATIONS

1. (c)

- Load is transmitted by friction only. Because of the clamping action, the bolts are not subjected to shear and bearing.
- HSFG bolts are made from medium carbon steel.

2. (d)

Case I:

Single-V groove weld : In this case, incomplete penetration results due to single-V groove weld. Hence, throat thickness

$$t_e = \frac{5}{8} \times t = \frac{5}{8} \times 12 = 7.5 \text{ mm}$$

$$\text{Effective length weld, } L_w = 150 \text{ mm}$$

$$\text{Strength of weld, } P_1 = \frac{L_w t_e f_y}{\gamma_{mw}} = \frac{150 \times 7.5 \times 250}{1.25 \times 1000}$$

$$P_1 = 225 \text{ kN}$$

Case II :

Double-V groove weld : In this case, complete penetration takes place.

Throat thickness = Thickness of thinner plate = 12 mm

$$\text{Strength of weld, } P_2 = \frac{L_w t_e f_y}{\gamma_{mw}} = \frac{150 \times 12 \times 250}{1.25 \times 1000}$$

$$= 360 \text{ kN}$$

$$P_2 - P_1 = 360 \text{ kN} - 225 \text{ kN} = 135 \text{ kN}$$

3. (d)

As per **IS 875 Part 3 Clause 5.3**

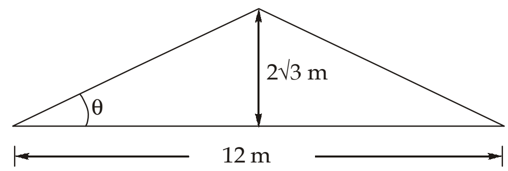
Design wind speed at any height 'z' in m/s

$$V_Z = V_b \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4$$

where,
k_1 = Probability factor (Risk coefficient)
k_2 = Terrain roughness and height factor
k_3 = Topography factor
k_4 = Importance factor the cyclonic region

4. (b)

$$\text{Span} = 12 \text{ m}$$
$$\text{Pitch} = 2\sqrt{3} \text{ m}$$
$$\text{Spacing} = 3.5 \text{ m c/c}$$



$$\theta = \tan^{-1}\left(\frac{2\sqrt{3}}{12/2}\right) = \tan^{-1}\frac{\sqrt{3}}{3} = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$$

$\Rightarrow$ $$\theta = 30°$$

Live load deduction for slope more than 10° = 0.75 – 0.02 × (30 – 10)

$= 0.35 \text{ kN/m}^2$

However as per IS875 (Part 2), minimum LL to be considered for design = 0.4 kN/m^2.

5. (d)

$$T_{db1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{mo}} + \frac{0.9 f_u A_{tn}}{\gamma_{m_1}}$$

$$= \left[\frac{1440 \times 250}{\sqrt{3} \times 1.1} + \frac{0.9 \times 410 \times 372}{1.25}\right] \times 10^{-3} \text{ kN} = 298.765 \text{ kN}$$

$$T_{bd2} = \frac{0.9 f_u A_{vn}}{\sqrt{3}\,\gamma_{m1}} + \frac{f_y A_{tg}}{\gamma_{mo}}$$

$$= \left[\frac{0.9 \times 410 \times 900}{\sqrt{3} \times 1.25} + \frac{250 \times 480}{1.1}\right] \times 10^{-3}$$

$$= 262.481 \text{ kN}$$

$\therefore$ Block shear strength = Minimum[298.765, 262.481] = 262.481 kN $\simeq$ 262.48 kN

6. (a)

According to clause 8.7.9 of IS 800: 2007,

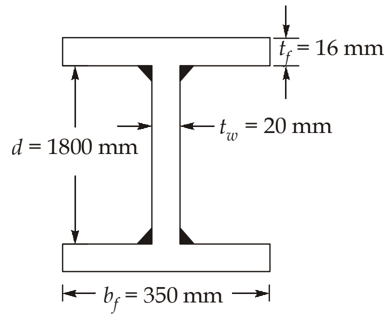
$$I_s \geq 0.34\, \alpha_s\, D^3\, t_{cf}$$

where α_s is constant which depends on $\dfrac{kL}{r_y}$

D = Overall depth of beam at support (mm)

t_{cf} = Maximum thickness of compression flange in the span under consideration (mm)

7. (b)



$$b = \frac{350-20}{2} = 165 \text{ mm}$$

$$\in = \sqrt{\frac{250}{f_y}} = \sqrt{\frac{250}{250}} = 1$$

For flange, $$\frac{b}{t_f} = \frac{165}{16} = 10.3125$$

∴ $$9.4\in < 10.3125 < 13.6\in$$

Hence flange is semicompact.

For web, $$\frac{d}{t_w} = \frac{1800}{20} = 90$$

$$84\in < 90 < 105\in$$

Hence web is compact.

So, overall section is semi-compact.

8. (b)

$$t_s = \sqrt{\frac{2.5w\left(a^2 - \mu b^2\right)\gamma_{m0}}{f_y}}$$

$$w = \frac{1600 \times 10^3}{450 \times 350} = 10.16 \text{ MPa}$$

$$t_s = \sqrt{\frac{2.5 \times 10.16 \times \left(50^2 - 0.3 \times 50^2\right) \times 1.1}{250}}$$

$$= 13.98 \simeq 14 \text{ mm}$$

10. (a)

As per **IS 800:2007**, **Clause 10.3.3.3**, the design shear capacity of bolts carrying shear through packing plate in excess of 6 mm shall be decreased by a factor of (β_{pk}).

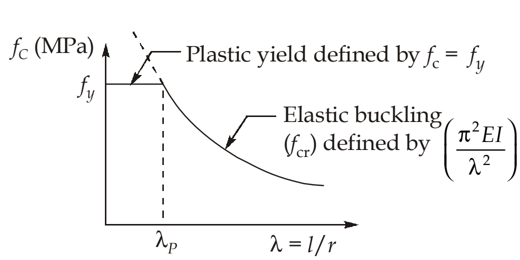
$$\beta_{pk} = 1 - 0.0125\, t_{pk}$$

$$= 1 - 0.0125 \times 8$$

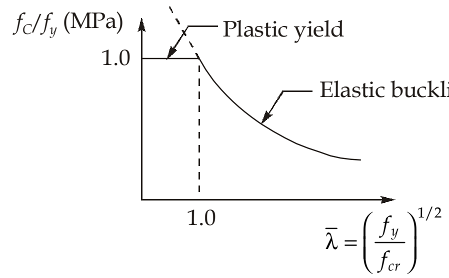
$$= 0.9$$

11. (c)

Strength curve for an axially loaded initially straight pin ended column is given by



Strength curve



Strength curve in a non-dimensional form

12. (a)

Reduction in plastic section modulus due to application of shear force is given as

$$\left[Z_{pw}\left(1-\sqrt{(1-q^2)}\right)\right]$$

where

$$z_{pw} = \text{plastic section modulus of web}$$

$$= \frac{(400-2\times16)^2\times8.9}{4}$$

$$q = \frac{V}{V_p} = \left[\frac{\text{Shear force}}{\text{Shear capacity}}\right]$$

$$\text{Shear capacity} = \frac{A_w f_y}{\sqrt{3}} = 0.577\, A_w f_y$$

$$= 0.577 \times f_y \times dt_w$$

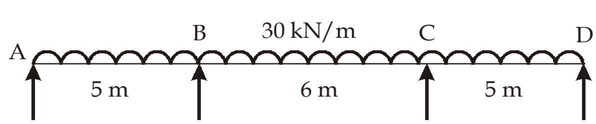
$$q = \left(\frac{310\times1000}{0.577\times250\times400\times8.9}\right) = 0.6$$

Hence reduction in plastic section modulus

$$= \frac{(400-2\times16)^2\times8.9}{4}\times\left(1-\sqrt{1-(0.6)^2}\right)$$

$$= 60.26 \times 10^3\ \text{mm}^3$$

13. (b)



For beams *AB* and *CD*,

They will act as propped cantilevers, hence

$$M_p = \frac{wl^2}{11.656} = \frac{30\times5^2}{11.656} = 64.34\ \text{kNm}$$

For beam *BC*,

$$M_p = \frac{wl^2}{16} = \frac{30\times6^2}{16} = 67.5 \text{ kNm}$$

$\therefore$ Required plastic moment capacity of beam is 67.5 kNm. [Greater of the above 2 values]

14. (c)

$$\text{Slenderness ratio, } \lambda = \frac{l}{r}$$

$$r = \frac{t}{\sqrt{12}} = \frac{12}{\sqrt{12}} = \sqrt{12}$$

$$\lambda = \frac{360}{\sqrt{12}} = 103.92 \simeq 104 \qquad (\le 145) \text{ OK}$$

15. (c)

When more number of bolts are provided than required, the net section [$(B - nd_o)t$] of plate reduces and it will then fail in net section rupture.

16. (c)

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

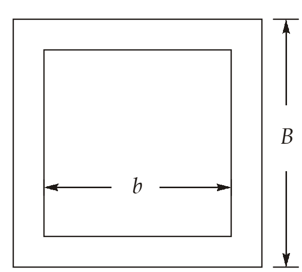
But $$0.7 \le \beta \le \frac{0.9 f_u/\gamma_{m1}}{f_y/\gamma_{m0}}$$

$\Rightarrow$ $$\beta \le \frac{0.9\times410/1.25}{250/1.1}$$

$$\beta \le 1.3$$

$$\text{Hence maximum value of } \beta = 1.3$$

17. (a)



$$Z_{ez} = \frac{I_z}{B/2} = \left(\frac{B^4}{12} - \frac{b^4}{12}\right)\times\frac{2}{B} = \frac{B^4 - b^4}{6B}$$

$$z_{pz} = \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$$

$$A_C = A_t = \frac{B^2 - b^2}{2}$$

$$\bar{y} = \bar{y}_1 = \bar{y}_2 = \frac{\frac{B^2}{2}\left(\frac{B}{4}\right) - \frac{b^2}{2}\left(\frac{b}{4}\right)}{\left(\frac{B^2 - b^2}{2}\right)} = \frac{1}{4}\left(\frac{B^3 - b^3}{B^2 - b^2}\right)$$

$$z_{pz} = \frac{A}{2}(\bar{y}_1 + \bar{y}_2) = A\bar{y} = (B^2 - b^2)\left[\frac{1}{4}\left(\frac{B^3 - b^3}{B^2 - b^2}\right)\right]$$

$\Rightarrow$
$$z_{pz} = \left(\frac{B^3 - b^3}{4}\right)$$

$\therefore$
$$\text{S.F.} = \frac{Z_{pz}}{Z_{ez}} = \frac{B^3 - b^3}{4} \times \left(\frac{6B}{B^4 - b^4}\right)$$

$\Rightarrow$
$$\text{S.F.} = \frac{3}{2}\left[\frac{1 - (b/B)^3}{1 - (b/B)^4}\right]$$

Since
$$\frac{b}{B} = k$$

$\therefore$
$$\text{S.F.} = \frac{3}{2}\left(\frac{1 - k^3}{1 - k^4}\right)$$

18. (b)

Since $V < 0.6V_d$ (Low shear case)

$$M_d = \frac{\beta_b z_p f_y}{\gamma_{m0}} \le \frac{1.2 z_e f_y}{\gamma_{m0}}$$

β_b = 1.0 for plastic and compact section

$\therefore$
$$M_d = \frac{1.0 \times 260 \times 10^3 \times 250}{1.1} \text{ Nmm}$$
$$= 59.1 \text{ kNm}$$

But
$$M_d \le \frac{1.2 z_e f_y}{\gamma_{m0}} = \frac{1.2 \times 200 \times 10^3 \times 250}{1.1} \text{Nmm}$$
$$= 54.55 \text{ kNm}$$

Hence,
$$M_d = 54.55 \text{ kNm}$$

19. (c)

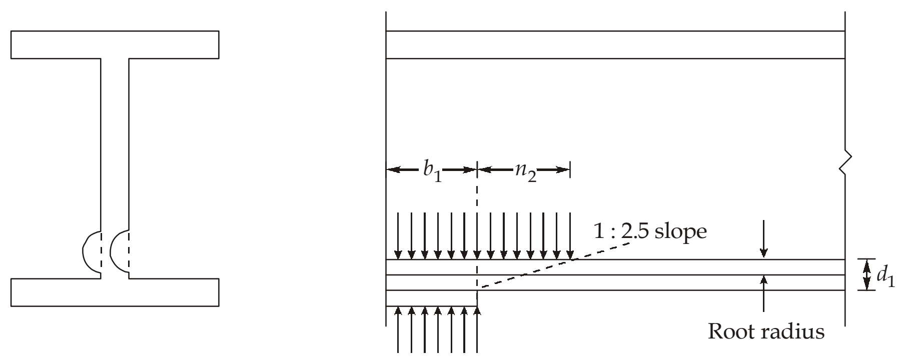
$$\text{Direct shear stress, } q = \frac{P}{2ht} = \frac{100 \times 10^3}{2 \times 250 \times 5} \text{ MPa}$$
$$= 40 \text{ MPa}$$

$$\text{Bending stress (maximum), } f = \frac{M}{Z} = \frac{Pe}{\frac{2th^2}{6}} = \frac{3Pe}{th^2}$$

$$= \frac{3 \times 100 \times 10^3 \times 100}{5 \times 250 \times 250} = 96 \text{ MPa}$$

$$\text{Equivalent stress} = \sqrt{f^2 + 3q^2} = \sqrt{(96)^2 + 3(40)^2} = 118.4 \text{ MPa}$$

20. (d)

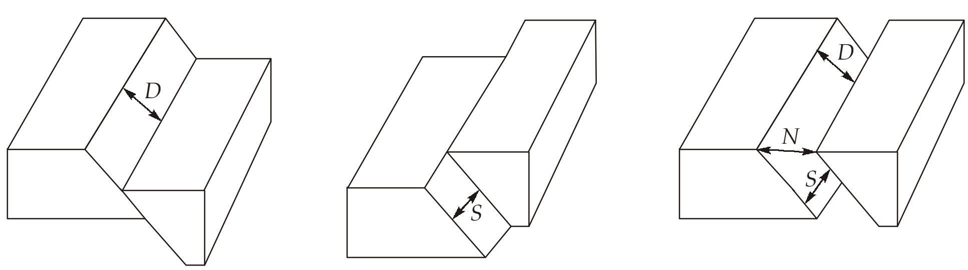


$$F_{crip} = \frac{(b_1 + n_2) \times t_w \times f_{yw}}{\gamma_{m0}}$$

$$= \frac{(b_1 + 2.5d_1)t_w f_{yw}}{\gamma_{m0}}$$

22. (b)

The displacement that occurs during faulting is called the slip. The total displacement is known as the net slip. This may be along the strike direction (strike slip) or the dip direction (dip slip) or along both as shown below.



Dip slip **Strike slip** **Net slip**

$$\text{Net slip} = \left(\sqrt{(\text{Strike slip})^2 + (\text{Dip slip})^2}\right)$$

23. (a)

$$e = \pm a\,(n)^{1/2}$$

$$= \pm\, 4(3)^{1/2} = \pm\, 6.93''$$

24. (a)

- A disconformity is an unconformity between parallel layers of sedimentary rocks which represent a period of erosion or non-deposition.
- A non conformity exists between sedimentary rocks and metamorphic or igneous rocks when the sedimentary rock lies above and was deposited on the pre-existing and eroded metamorphic or igneous rock.
- An angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers.
- Statement (i) refers to angular unconformity.
- When two sets of beds are parallel and the contact is a simple bedding plane, the unconformity is called paraunconformity.

25. (a)

$$h_2 - h_1 = S_1 - S_2 = S$$

$$h_1 = D\tan\theta_1$$

$$h_2 = (D + d)\tan\theta_2$$

$$\therefore \quad h_2 - h_1 = (D + d)\tan\theta_2 - D\tan\theta_1$$

$$\Rightarrow \quad S = D(\tan\theta_2 - \tan\theta_1) + d\tan\theta_2$$

$$\Rightarrow \quad D = \frac{(d\tan\theta_2 - S)}{(\tan\theta_1 - \tan\theta_2)}$$

$$\therefore \quad h_1 = D\tan\theta_1$$

$$\Rightarrow \quad h_1 = \frac{(d\tan\theta_2 - S)\tan\theta_1}{(\tan\theta_1 - \tan\theta_2)}$$

$$\therefore \quad \text{R.L. of } F = \text{R.L. of B.M.} + S_1 + h_1$$

26. (b)

- Statement 1 corresponds to Mie scattering.
- Remote sensing methods are any methods where information/data is extracted or interpreted by indirect measurement of the object under study.

27. (b)

Area of ground = 220 km^2

Overlap: Longitudnal = 70%; Lateral = 40%

Scale : 1 cm = 100 m = 0.1 km

Number of photographs required is given as,

$$N = \frac{220 \times 10^6 \text{ m}^2}{\left(30 \text{ cm} \times \frac{100 \text{ m}}{1 \text{ cm}}\right) \times \left(30 \text{ cm} \times \frac{100 \text{ m}}{1 \text{ cm}}\right) \times (1 - 0.7)(1 - 0.4)}$$

$$= 135.8 \simeq 136$$

28. (c)

- Profile levelling is done along the centre line of a proposed route, road or a railway at suitable intervals whereas cross sectioning is the process of levelling across the centre line.
- Optical transfer of control is used in open cast mining or it may be used for shallow tunnels.

29. (a)

- Collimation system is suitable for longitudinal levelling where there are a number of intermediate sights, whereas rise and fall system is suitable for fly levelling where there are no intermediate sights.
- Curvature correction is negative whereas refraction correction is positive.

$$\text{Curvature correction, } c_c = \frac{-d^2}{2R} (\text{Always negative})$$

$$\text{Refraction correction} = \frac{1}{7}(c_c) = \frac{d^2}{14R} (\text{Always positive})$$

30. (d)

Axis of the telescopic level must be parallel to the line of collimation.

31. (a)

- Plane table surveying is very suitable for preparing small scale maps.
- Many features can be accurately represented, as the surveyor has the objects or features in view while plotting.
- This method is suitable in magnetic areas, where a compass survey will not be reliable.
- It is not suitable when accuracy is required.

32. (c)

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

Mean base length in the photograph, b = 102.5 mm

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

$$\text{Parallax is given by } \frac{Bf}{(H-h)}$$

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

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

$$\text{Difference in parallax} = 104.46 - 102.5 = 1.96 \text{ mm}$$

33. (d)

The horizontal distance is given by

$$D = \left(\frac{f}{i}\right)s + c$$

If δD = error in distance

and δi = error in the stadia interval,

We get,

$$\delta D = -s\left(\frac{f}{i^2}\right)\delta i \quad \text{...(i)}$$

Now, $\frac{f}{i} = 200$

or $i = \frac{f}{200} = \frac{20}{200} = 0.1$ cm

Substituting the values of $\frac{f}{i}$, i and δi in (i), we get

$$\delta D = (-s) \times \frac{f}{i} \times \frac{1}{i} \times \delta i$$

$$= (-60) \times 200 \times \frac{1}{0.1} \times 0.0025 \text{ cm}$$

$$= 300 \text{ cm}$$

35 (d)

The effective length of fillet weld is taken as its overall length minus 2 times the size of weld.

37. (d)

A tubular compass is an improved version of a trough compass. A trough compass does not lend itself to very precise setting owing to parallax arising from the difficulty of ensuring that the eye is in the vertical plane of the needle. This difficulty is overcome by the use of a tubular compass. In a tubular compass, the magnetic needle is contained in a tube, at one end of which an eye piece and a diaphragm carrying a glass plate with vertical rulings is fitted. This is nearly in the same plane as one end of the needle. The reticule being suitably illuminated by a reflector, the observer on looking through the eye piece, sees the end of the needle without any parallax.

39. (d)

In analysis of statically determinate structure, no consideration is given to the compatibility because the components of such structure always fit together without any straining, and slight change in dimension only produces small alterations in the geometry, with the corresponding change in the forces.

40. (c)

$$\Delta t = 78 - 24 = 54°C$$

Actual decrease in length after walls yield by δ, $\Delta l = l\alpha\Delta t - \delta$

$$\text{Actual temperature strain, } \in = \frac{\alpha l \Delta t - \delta}{l}$$

$$\text{Pull exerted on the walls, } F = AE\in = AE\left[\frac{\alpha l \Delta t - \delta}{l}\right]$$

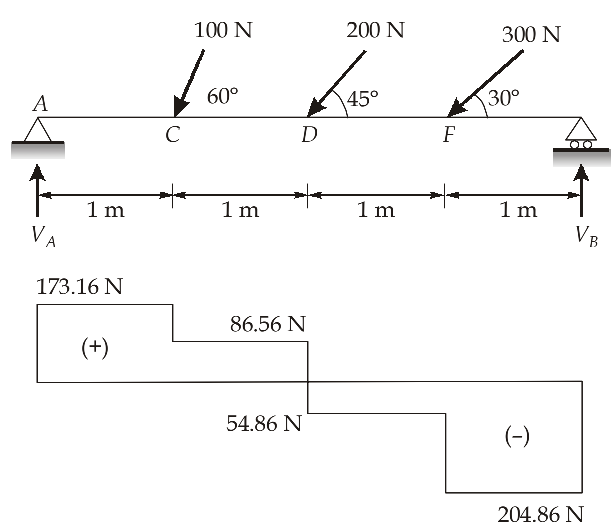
$$\Rightarrow \quad F = 500 \times 200 \times 10^3 \times \left[\frac{11 \times 10^{-6} \times (6 \times 10^3) \times 54 - 2}{6000}\right]$$

$$\Rightarrow \quad F = 26066.67 \text{ N} = 26.07 \text{ kN}$$

41. (d)

For rubber, Poisson's ratio is in range of 0.45 to 0.50.

42. (a)



$$\Sigma M_A = 0$$

$$\Rightarrow \quad 4 \times V_B = 300 \sin 30° \times 3 + 200 \sin 45° \times 2 + 100 \sin 60° \times 1$$

$$\Rightarrow \quad V_B = 204.86 \text{ N}$$

$$\therefore \quad V_A = 378.02 - V_B = 173.16 \text{ N}$$

So, maximum bending moment will occur when *SF* diagram changes sign so, it occurs at 2m from *B*.

43. (d)

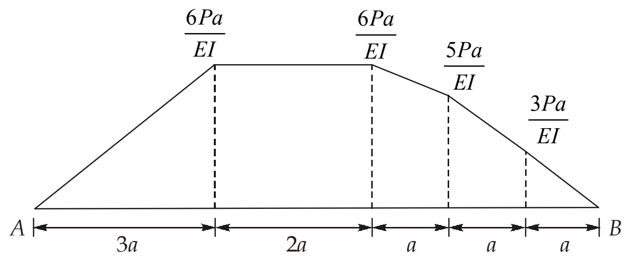
$$M_A = 0$$

$$\Rightarrow \quad V_B \times 8a = P \times 7a + P \times 6a + P \times 5a + 2P \times 3a$$

$$\Rightarrow \quad V_B = 3P$$

$$\text{So,} \quad V_A = 5P - V_B = 2P$$

Drawing $\frac{M}{EI}$ diagram for above beam

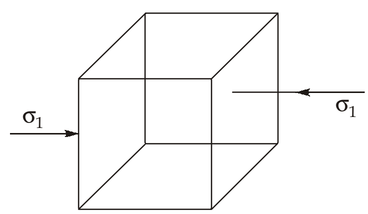


So, $\theta_A - \theta_B$ is area of $\frac{M}{EI}$ diagram between A and B *i.e.*

$$\theta_A - \theta_B = \frac{1}{2}\times 3a \times \frac{6Pa}{EI} + \frac{6Pa}{EI}\times 2a + \frac{1}{2}\times a \times \left(\frac{6Pa}{EI}+\frac{5Pa}{EI}\right) + \frac{1}{2}\times a \times \left(\frac{5Pa}{EI}+\frac{3Pa}{EI}\right) + \frac{1}{2}\times a \times \frac{3Pa}{EI}$$

$$\Rightarrow \qquad \theta_A - \theta_B = \frac{32Pa^2}{EI}$$

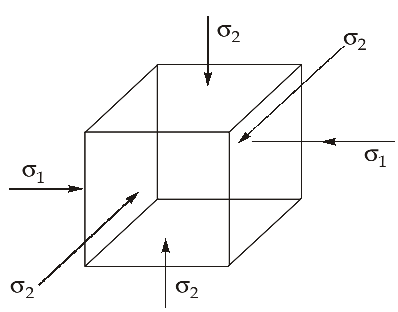
44. (c)



When σ_1, acting alone, strain in lateral direction is

$$\varepsilon_l = \frac{-\mu(-\sigma_1)}{E} = \frac{\mu\sigma_1}{E}$$

When compressive strain is acting in all lateral directions,



Strain in lateral direction

$$\varepsilon_l' = \frac{-\sigma_2}{E} - \mu\left(\frac{-\sigma_2}{E}\right) - \mu\left(\frac{-\sigma_1}{E}\right)$$

$$\Rightarrow \qquad \varepsilon_l' = \frac{\mu\sigma_1 + \mu\sigma_2 - \sigma_2}{E}$$

According to question,

$$\varepsilon_l' = \frac{1}{4}\varepsilon_l$$

$$\Rightarrow \quad \frac{\mu\sigma_1}{E} + \frac{\mu\sigma_2}{E} - \frac{\sigma_2}{E} = \frac{\mu}{4}\frac{\sigma_1}{E}$$

$$\Rightarrow \quad \frac{3}{4}\mu\sigma_1 = (1 - \mu)\,\sigma_2$$

$$\Rightarrow \quad \frac{3}{4} \times 0.3\sigma_1 = (1 - 0.3)\,\sigma_2$$

$$\Rightarrow \quad \frac{\sigma_2}{\sigma_1} = \frac{0.9}{4 \times 0.7}$$

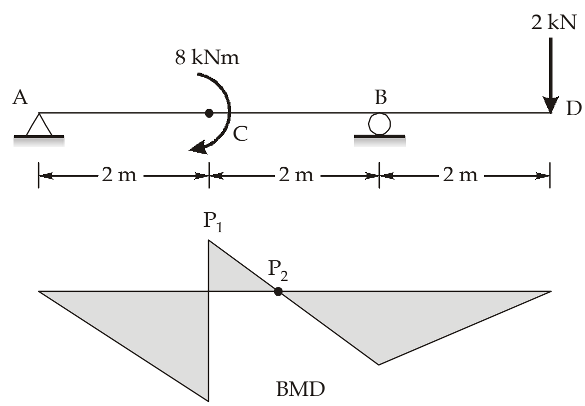
$$\Rightarrow \quad \frac{\sigma_2}{\sigma_1} = \frac{9}{28}$$

45. (b)

$$R_B = \frac{8+12}{4} = 5\,\text{kN}$$

$$R_A = 3\text{ kN} \downarrow$$

BMD is shown. There are 2 points of contra-flexure.



46. (a)

$$\text{Longitudinal strain} = -\frac{\delta L}{L} = \frac{0.075}{30} = -2.5 \times 10^{-3}$$

$$\text{Lateral strain} = \frac{\delta b}{b} = \frac{0.003}{4} = 7.5 \times 10^{-4}$$

$$\text{Poisson's ratio} = \frac{-\text{Lateral strain}}{\text{Longitudnal strain}} = \frac{7.5 \times 10^{-4}}{2.5 \times 10^{-3}} = 0.3$$

$$\text{Longitudinal strain} = \frac{P}{AE}$$

$$\Rightarrow \quad 2.5 \times 10^{-3} = \frac{400 \times 10^3}{1600 \times E}$$

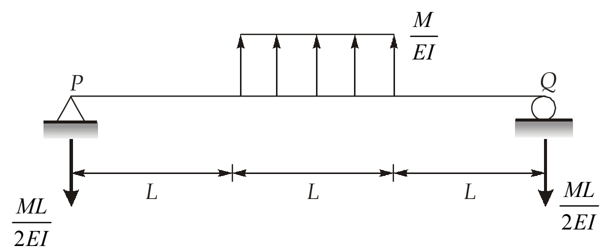
$$\Rightarrow \quad E = 10^5\ \text{N/mm}^2$$

$$E = 2G\,(1 + \mu)$$

$$\Rightarrow \quad 10^5 = 2 \times G(1 + 0.3)$$
$$G = 38461.54 \text{ N/mm}^2$$

47. (b)

Conjugate beam of given beam is

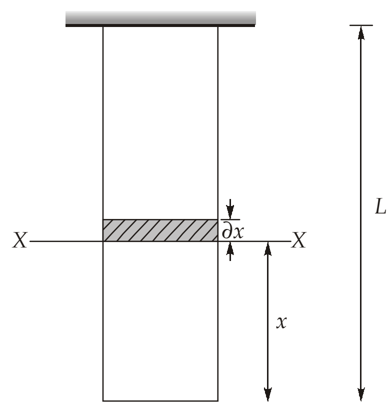


Δ_{max} is the *BM* of conjugate beam and will occur at mid span.

$$\Delta_{max} = \frac{-ML}{2EI} \times \left(L + \frac{L}{2}\right) + \frac{M}{EI} \times \frac{L}{2} \times \frac{L}{4}$$

$$\Delta_{max} = \frac{-5ML^2}{8EI}$$

48. (c)



$$W_x = \text{weight of bar of length } x$$
$$= A \times x \times \delta$$
$$= \delta A x$$

$$\therefore \quad \text{Stress} = \frac{\delta A x}{A} = \delta x$$

$$\because \quad E = \frac{\text{stress}}{\text{strain}}$$

$$= \frac{\delta x}{\frac{\partial \delta}{\partial x}} = \frac{\delta x \partial x}{\partial \delta}$$

Strain energy stored in portion ∂x is given by

$$dU = \text{Average weight} \times \text{elongation of } \partial x \text{ length}$$

$$dU = \left(\frac{1}{2} \times W_x\right) \times \partial\delta$$

$$= \frac{1}{2}\delta Ax \times \frac{\delta x dx}{E}$$

$$= \frac{1}{2}\delta^2 Ax^2 \frac{dx}{E}$$

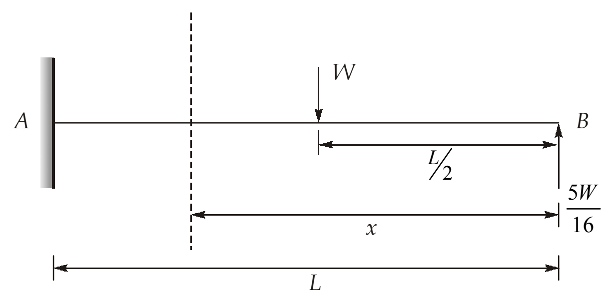
$$\therefore \quad U = \int_0^L \frac{\delta^2}{2}\frac{Ax^2}{E}dx$$

$$= \frac{1}{2}\delta^2 \frac{A}{E}\int_0^L x^2 \partial x$$

$$= \frac{1}{2}\delta^2 \frac{A}{E}\left[\frac{x^3}{3}\right]_0^L$$

$$= \frac{A\delta^2 L^3}{6E}$$

49. (b)

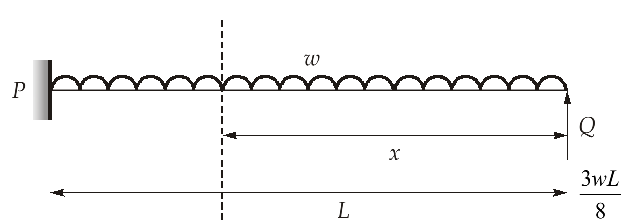


$$\frac{5W}{16}x = W\left(x - \frac{L}{2}\right)$$

$$\Rightarrow \quad \frac{11x}{16} = \frac{L}{2}$$

$$x = \frac{8L}{11}$$

$\therefore$ Distance from ends $A = L - x = L - \frac{8L}{11} = \frac{3L}{11}$



$$\frac{3}{8}wLx = \frac{wx^2}{2}$$

$$\Rightarrow \quad x = \frac{3L}{4}$$

$$\therefore \quad \text{Distance from end } P = L - x = L - \frac{3L}{4} = \frac{L}{4}$$

51. (b)

Given : $E_S = 2 \times 10^5$ MPa, $E_t = 10^4$ MPa

NA from bottom = 86.76 mm

If an equivalent timber section = 230.9×10^6

$$M_{\max} = \frac{1.2 \times 8^2}{8} = 9.6\,\text{kNm}$$

$$\sigma_{c\text{ timber}} = \frac{My}{I}$$

$$= \frac{9.6 \times 10^6 (200 - 86.76)}{230.9 \times 10^6}$$

$$= 4.708\text{ N/mm}^2$$

$$\sigma_{c\text{ steel}} = \frac{m \times y'}{y} \times \sigma_{c\text{ timber}}$$

$y' \rightarrow$ distance from NA to top point of steel

$$= 20 \times \frac{63.24}{113.24} \times 4.708$$

$$m = \frac{(MOE)_s}{(MOE)_t}$$

$$= 52.58\text{ N/mm}^2$$

52. (c)

$$M_{D_{\text{right}}} = 0$$

$\Rightarrow \quad V_E \times 10 = 10 \times 5$

$\Rightarrow \quad V_E = 5\text{kN}$

$M_{D\text{ left}} = 0$

$\Rightarrow \quad V_A \times 20 + V_B \times 10 = 3 \times 10 \times 15 + 10 \times 5$

$\Rightarrow \quad 20\,V_A + 10V_B = 500$

$\Rightarrow \quad 2V_A + V_B = 50$ .....(i)

Also, $\Sigma F_y = 0$

$\Rightarrow \quad V_A + V_B + V_E = 3 \times 10 + 10 + 10$

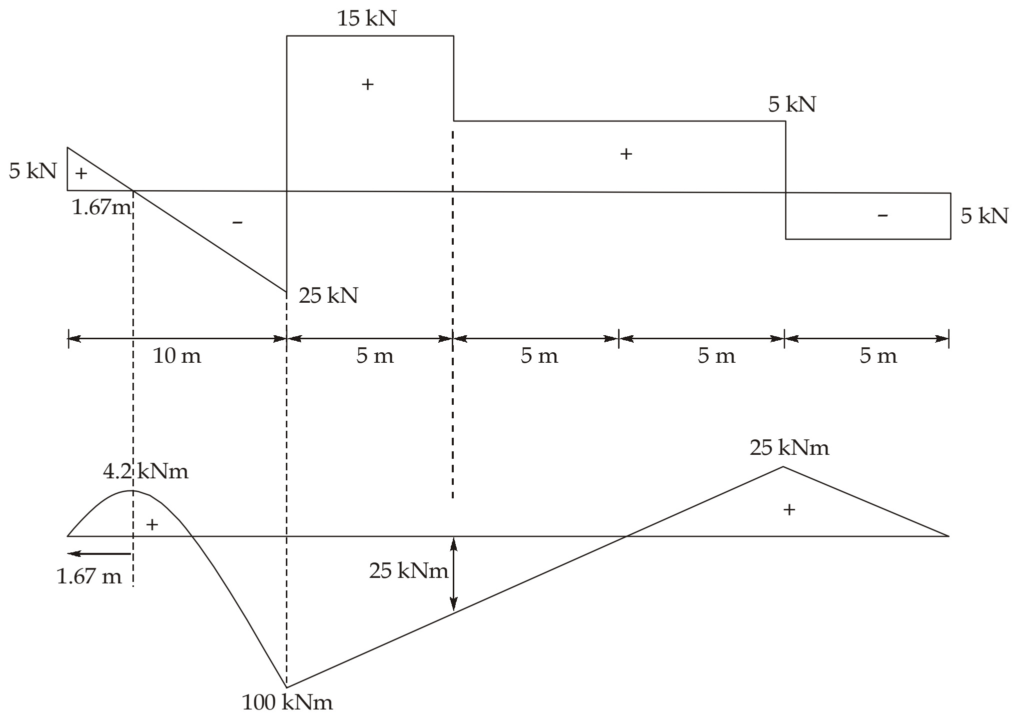
$\Rightarrow \quad V_A + V_B + 5 = 50$

$V_A + V_B = 45$ .....(ii)

From (i) and (ii)

$V_A = 5\text{kN}$

$V_B = 40\text{ kN}$



∴ Maximum value of BM = 100 kNm

56. (c)

The stress–strain curve used need not to be linear in order for material to be elastic.

57. (d)

- The static cone penetration test, simply called the cone penetration test (CPT), is a simple test that is now widely used in place of SPT, particularly for soft clays and silts and fine to medium sand deposits. The test was developed in Holland and is, therefore also known as the Dutch cone test.
- CPT gives a continuous record of variation of both cone resistance and friction resistance with depth. Unlike the SPT and the DCPT, this test measures the static resistance of the soil. CPT, however, does not yield any sample. The test is also unsuitable in gravels and very dense sands owing to the difficulty experienced in pushing the cone and the anchorage system.

58. (b)

Open drive thin wall samplers are suitable for sampling of soils possessing some cohesion. Thick walled samplers are used for obtaining disturbed but representative soil samples.

59. (d)

$$P_u = \alpha \bar{c} A$$
$$= 0.8 \times 60 \times \pi \times 0.6 \times 14$$
$$= 1266.69 \text{ kN}$$
$$\simeq 1266 \text{ kN}$$

60. (c)

$$F = \frac{c + \gamma' z \cos^2 i \tan\phi}{\gamma_{sat} z \cos i \sin i}$$

$$= \frac{8 + (19 - 9.81) \times 0.98^2 \times 0.404 \times 4}{19 \times 4 \times 0.21 \times 0.98}$$

$$= 1.42$$

62. (a)

Cellular coffer dams are more advantageous than braced coffer dams.

63. (b)

Ultimate bearing capacity in clay is independent of size of footing.

64. (a)

Ultimate bearing capacity is given by

Circular footing: $Q_{uc} = 1.3\, cN_c + \gamma D_f N_q + 0.3\, B'\gamma N_\gamma$

Square footing: $Q_{us} = 1.3\, cN_c + \gamma D_f N_q + 0.4\, B\gamma N_\gamma$

For cohesionless soil, $c = 0$

For footing on surface of soil, $D_f = 0$

$$\therefore \quad \frac{Q_{uc}}{Q_{us}} = \frac{0.3 \times 2B\gamma N_y}{0.4\, B\gamma N_\gamma} = \frac{0.3 \times 2}{0.4} = 1.5 \qquad (\because \; B' = 2B)$$

65. (c)

Uniaxial Geogrids : These geogrids are formed by the stretching of ribs in the longitudinal direction. So, in this case, the material possesses high tensile strength in the longitudinal direction than on the transverse direction. These are used for soil reinforcement applications, such as retaining walls, steepened slopes, embankments over soft soils, and waste containment applications.

Biaxial Geogrids : Here during the punching of polymer sheets, the stretching is done in both directions. Hence the function of tensile strength is equally given to both transverse and longitudinal direction. These are used for soil reinforcement application such as aggregate base course reduction, steepened slopes, embankments over soft soils, and waste containment applications.

66. (c)

Ozone disinfection is costly and has a very short life of disinfection. It does not provide prolonged safety from contamination.

67. (c)

Generally the sewer pipes of sizes less than 0.4 m diameter are designed as running half full at maximum discharge, and the sewer pipes greater than 0.4 m in diameter are designed as running $\left(\frac{2}{3}\right)^{\text{rd}}$ or $\left(\frac{3}{4}\right)^{\text{th}}$ full at maximum discharge. To prevent the sewer from getting silted up, the minimum velocity has to be limited.

68. (a)

Given, $d = 0.5D$

$\Rightarrow \quad \frac{d}{D} = 0.5$

$\Rightarrow \quad q = 600 \text{ lps} = 0.6 \text{ m}^3/\text{sec}$

$s = 0.0004$

$n = 0.0157$

As $\frac{d}{D} = \frac{q}{Q} = 0.5$

$\therefore \quad Q = \frac{q}{0.5} = \frac{0.6}{0.5} = 1.2 \text{ cumecs}$

Using Manning's equation,

$$Q = \frac{1}{n} AR^{2/3} S^{1/2}$$

$$\Rightarrow \quad 1.2 = \frac{1}{0.0157} \times \left(\frac{\pi}{4} \times D^2\right) \times \left(\frac{D}{4}\right)^{2/3} \times \sqrt{0.0004}$$

$$\Rightarrow \quad \frac{1.2 \times 0.0157 \times 2.52 \times 50 \times 4}{\pi} = D^{8/3}$$

$\Rightarrow \quad D = (3)^{0.375}$

$\Rightarrow \quad D = 1.51 \text{ m}$

Hence, Radius = 0.75 m

69. (c)

Saturation, DO = 9.2 mg/l

Initial, DO = 8.5 mg/l

$\therefore$ Initial DO deficit, D_0 = 9.2 – 8.5 = 0.7 mg/l

The time at which DO is minimum is given by,

$$t_c = \frac{1}{k_2 - k_1} \ln\left[\frac{k_2}{k_1}\left[1 - \frac{D_0 (k_2 - k_1)}{k_1 L_0}\right]\right]$$

$$= \frac{1}{0.4 - 0.25} \ln\left[\frac{0.4}{0.25}\left[1 - \frac{0.7(0.4 - 0.25)}{0.25 \times 25}\right]\right]$$

$$= \frac{1}{0.15} \times \ln 1.57312 = \frac{1}{0.15} \ln 1.57 = \frac{0.45}{0.15} = 3 \text{ days}$$

70. (a)

Leachate is a toxic fluid formed in landfills. It cannot be used directly as a biofuel. Landfill leachate can potentially become an asset as a sustainable source of water and nutrient for cultivating microalgae for biofuel.

For better biological degradation, the moisture should be high, say not less than 60%.

71. (b)

Emission of dioxins takes place from incinerators. Fly ash produced from incinerators is often found to be highly contaminated with substances like lead and hence has to be treated as a hazardous waste.

73. (a)

Gravity thickners are never employed for secondary sludge thickening independently as the weight of solids in secondary sludge is comparatively very less.

75. (d)

For proper development of anaerobic digestion, C/N ratio of the digestive material should be between 30 to 50 for optimum digestion.

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