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# ESE 2022 : 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. | (d) | 16. | (a) | 31. | (b) | 46. | (b) | 61. | (c) |
| 2. | (a) | 17. | (c) | 32. | (c) | 47. | (c) | 62. | (c) |
| 3. | (b) | 18. | (c) | 33. | (a) | 48. | (a) | 63. | (a) |
| 4. | (c) | 19. | (c) | 34. | (d) | 49. | (d) | 64. | (d) |
| 5. | (b) | 20. | (b) | 35. | (a) | 50. | (c) | 65. | (a) |
| 6. | (d) | 21. | (a) | 36. | (d) | 51. | (b) | 66. | (d) |
| 7. | (a) | 22. | (d) | 37. | (b) | 52. | (a) | 67. | (b) |
| 8. | (c) | 23. | (c) | 38. | (a) | 53. | (d) | 68. | (a) |
| 9. | (d) | 24. | (c) | 39. | (a) | 54. | (d) | 69. | (a) |
| 10. | (b) | 25. | (b) | 40. | (b) | 55. | (c) | 70. | (c) |
| 11. | (c) | 26. | (d) | 41. | (c) | 56. | (d) | 71. | (c) |
| 12. | (b) | 27. | (c) | 42. | (d) | 57. | (a) | 72. | (d) |
| 13. | (b) | 28. | (a) | 43. | (b) | 58. | (d) | 73. | (b) |
| 14. | (d) | 29. | (c) | 44. | (b) | 59. | (b) | 74. | (c) |
| 15. | (a) | 30. | (d) | 45. | (b) | 60. | (d) | 75. | (c) |

## DETAILED EXPLANATIONS

**1. (d)**

Refer IS 800 : 2007.

**Clause 1.3.104 Stress Analysis:** The analysis of the internal force and stress condition in an element, member or structure.

**Clause 1.3.105 Stress Cycle Counting:** Sum of individual stress cycles from stress history arrived at using any rational method.

**Clause 1.3.106 Stress Range:** Algebraic difference between two extremes of stresses in a cycle of loading.

**Clause 1.3.107 Stress Spectrum:** Histogram of stress cycles produced by a nominal loading event design spectrum, during design life.

**2. (a)**

Refer IS 800 : 2007, Table 2.

**3. (b)**

$$\eta = \frac{\text{Least design strength per pitch length}}{\text{Design strength of the solid plate per pitch length}} \times 100$$

$$\Rightarrow \quad \eta = \frac{\min\left(V_{dsb}, V_{dpb}, T_{dg}, T_{dn}\right)}{T_g} \times 100$$

As strength of solid plate is governed by yielding

$$T_g = T_{dg} = 90 \text{ kN}$$

$$\Rightarrow \quad \eta = \frac{58}{90} \times 100$$

$$\Rightarrow \quad \eta = 64.44\%$$

**4. (c)**

**Minimum pitch:** Bolts should be placed at sufficient distance and a minimum pitch is ensured for the following reasons:

1. To prevent bearing failure of members between the two bolts.
2. To permit efficient installation of bolts, i.e., to ensure sufficient space to tighten the bolts, prevent overlaping of the washers and provide adequate resistance to tear-out of bolts.

**Maximum pitch**: Maximum pitch serves the following purposes:

1. To reduce the length of the connection and gusset plate, i.e., to have a compact joint.
2. To have uniform stress in the bolts.
3. To check failures in case of built-up tension or compression member.

**5. (b)**

Possible location of hinges. At fixed ends, under the load and at the point of change in cross-sectional area i.e.,

$$N = 4$$

$$D_s = 2$$

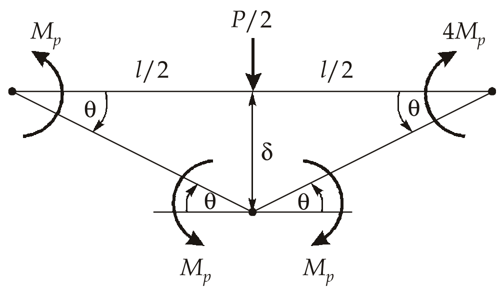
No. of plastic hinge required for collapse,

$$n = D_s + 1 = 2 + 1 = 3$$

∴ Number of independent mechanism

$$= N - D_s = 4 - 2 = 2$$

**Case-I:** Plastic hinges formed at *A*, *B* and *D*.




$$W_E = W_I$$

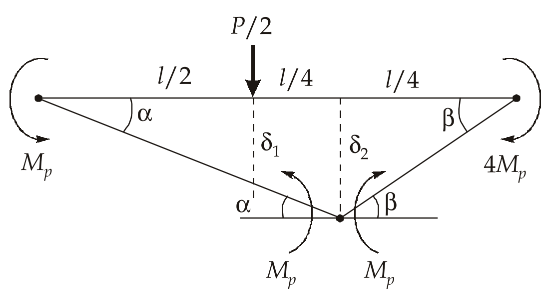
⇒
$$\frac{P}{2} \times \delta = M_p\theta + M_p\theta + M_p\theta + 4M_p\theta$$

$$\frac{P}{2} \times \delta = 7M_p\theta$$

$$\frac{P}{2} \times \delta = 7Mp\frac{\delta}{l/2}$$

$$P = \frac{28Mp}{l}$$

Case-II Hinges at *A*, *C*, *D*




$$\frac{3l}{4}\alpha = \frac{l}{4}\beta$$

$$\alpha = \frac{\beta}{3}$$

$$\beta = 3\alpha$$

$$w_i = w_E$$

$$2M_p\alpha + 5M_p\beta = \frac{P}{2} \times \frac{l}{2}\alpha$$

$$2M_p\alpha + 5M_p 3\alpha = \frac{Pl}{4}\alpha$$

$$17M_p\alpha = \frac{Pl}{4}\alpha$$

$$P_u = \frac{68M_p}{l}$$

$$\text{Collapse load} = \min\left(\frac{28Mp}{l}, \frac{68Mp}{l}\right) = \frac{28Mp}{l}$$

**6. (d)**

Upper yield point in a stress-strain curve for mild steel:

1. It depends on cross-sectional shape of the specimen.
2. It depends on the type of equipment used to perform the test.
3. The upper yield point is observed if load is applied rapidly whereas the lower yield point is observed if the rate of loading is slow.
4. In many hot-rolled steel sections, the upper yield point is not obtained due to residual stresses from the hot rolling process hence, it has no practical significance.

**7. (a)**

Refer IS 800 : 2007, Clause 11.1.2, 11.1.3 and 11.1.4.

**8. (c)**

The cost of the truss is inversely proportional to the spacing of trusses,

Hence, let, $t = \frac{C_1}{S}$ ...(1)

The cost of the purlins is directly proportional to the square of spacing of trusses,

Hence, let, $p = C_2S^2$ ...(2)

The cost of roof coverings is directly proportional to the spacing of trusses,

Hence, let, $r = C_3S$ ...(3)

Overall cost $x = t + p + r$

$$= \frac{C_1}{S} + C_2S^2 + C_3S$$

**9. (d)**

| Type of load | Additional load |
|---|---|
| (a) Vertical forces transferred to the rail. | |
| (i) For electric overhead cranes | 25% of maximum static wheel load |
| (ii) For head operated cranes | 10% of maximum static wheel load |
| (b) Horizontal forces transverse to the rails | |
| (i) For electric overhead cranes | 10% of the weight of the crab and the weight lifted on the crane |
| (ii) For hand operated cranes | 5% of the weight of the crab and the weight lifted on crane |
| (c) Horizontal forces along the rails | 5% of the static wheel load |

**10. (b)**

$$c = 2500 \text{ mm}$$
$$d = 2000 \text{ mm}$$

$\therefore$
$$c/d = \frac{2500}{2000} = 1.25 < \sqrt{2}$$

If
$$\frac{c}{d} < \sqrt{2} = 1.414$$

Then the required moment of inertia is given by

$$I \geq \frac{1.5 d^3 t_w^3}{c^2}$$

$$d = 2000 \text{ mm}$$
$$t_w = 10 \text{ mm}$$
$$c = 2500 \text{ mm}$$

$$I = \frac{1.5 \times (2000)^3 \times (10)^3}{(2500)^2}$$

$$\Rightarrow \quad I \geq 1920000 \text{ mm}^4$$
$$\Rightarrow \quad I \geq 192 \text{ cm}^4$$

**11. (c)**

Refer IS 800 : 2007 Clause 8.2.1.2.

**12. (b)**

$$\text{Effective slenderness ratio} = 1.1 \times 80 = 88 \text{ (battens)}$$

$$\text{Spacing of batten } \frac{c}{r_y} = \min.\begin{cases} 0.7 \times 88 \\ 50 \end{cases}$$

$$\Rightarrow \quad \frac{c}{r_y} = \min.\begin{cases} 61.6 \\ 50 \end{cases}$$

$$\Rightarrow \quad \frac{c}{r_y} \leq 50$$

$$\Rightarrow \quad c \leq 50 \times 26$$

$$\Rightarrow \quad c \leq 1300 \text{ mm}$$

**13. (b)**

Refer Clause 7.1.2.1 of IS 800 : 2007.

**14. (d)**

| S.No. | Type of Tension Member | Maximum Slenderness Ratio |
|---|---|---|
| 1. | Tension member in which there can be reversal of direct stress due to loads other than wind or earthquake force. | 180 |
| 2. | A member normally acting as a tie in a roof truss or a bracing system but subjected to possible reversal of stress due to wind or earthquake forces. | 350 |
| 3. | Tension member i.e., members always under tension (other than pretensioned members) | 400 |

**15. (a)**

For Fe410 grade steel, $f_u$ = 410 MPa

Shop welding, partial safety factor for material, $\gamma_{mw}$ = 1.25

Size of weld, $S$ = 6 mm

Effective throat thickness, $t = kS$

$= 0.7 \times 6 = 4.2$ mm

Effective length of weld, $L_w = \pi d$

$= \pi(160)$

$= 502.654$ mm

$$\text{Strength of weld} = \frac{L_w \times t \times f_u}{\gamma_{mw} \times \sqrt{3}}$$

$$= 502.654 \times 4.2 \times \frac{410}{1.25 \times \sqrt{3}} \text{ N}$$

$= 399.789$ kN

$$\text{Ultimate twisting moment} = 399.789 \times \frac{160}{2} \times 10^{-3} \text{kNm}$$

$= 31.98 \text{ kNm} \simeq 32$ kNm

**16. (a)**

$$\beta_{lg} = \frac{8d}{3d + l_g} \quad \text{when } l_g > 5d$$

**17. (c)**

For bolt $A$, direct shear, $$F_s = \frac{50}{5} = 10 \text{ kN}$$

Torsional shear, $$F_T = \frac{50 \times 10^3 \times 200 \times r}{4 \times r^2}$$

$$r = \sqrt{30^2 + 40^2} = 50 \text{mm}$$

$$\therefore \quad F_T = \frac{50 \times 10^3 \times 200 \times 50}{4 \times 50 \times 50} \text{N} = 50 \text{kN}$$

$$\therefore \quad \text{Ratio} = \frac{F_T}{F_S} = \frac{50}{10} = 5$$

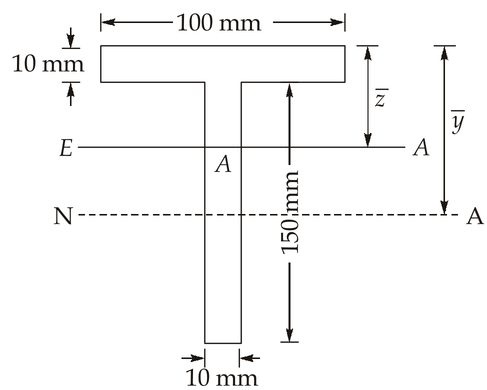
**18. (c)**

Let the distance of elastic neutral axis from top of Tee-section be $\bar{y}$.

$$\therefore \quad \bar{y} = \frac{100\times10\times5+150\times10\times85}{100\times10+150\times10} = 53\,\text{mm}$$

Let the plastic neutral axis by at $\bar{z}$ from top of Tee-section

$$\text{Total area of section} = 100 \times 10 + 150 \times 10 = 2500\ \text{mm}^2$$




Then, $$100\times10+(\bar{z}-10)\times10 = \frac{2500}{2}$$

$$\Rightarrow \quad 1000+(\bar{z}-10)10 = 1250$$

$$\Rightarrow \quad (\bar{z}-10)10 = 250$$

$$\Rightarrow \quad \bar{z}-10 = 25$$

$$\Rightarrow \quad \bar{z} = 35\ \text{mm}$$

The distance between elastic neutral axis and plastic neutral axis =53 – 35 = 18 mm

**19. (c)**

**Anticlines** are defined as those folds in which

(i) the strata are uparched, that is, these become CONVEX UPWARDS.

(ii) the geologically older rocks occupy a position in the interior of the fold, oldest being positioned at the core of the fold and the youngest forming the outermost flank (provided strata show normal order of superposition), and,

(iii) the limbs dip away from each other at the crest in the simplest cases. Symbolically, an anticline may be indicated by two arrows diverging from the central point, as

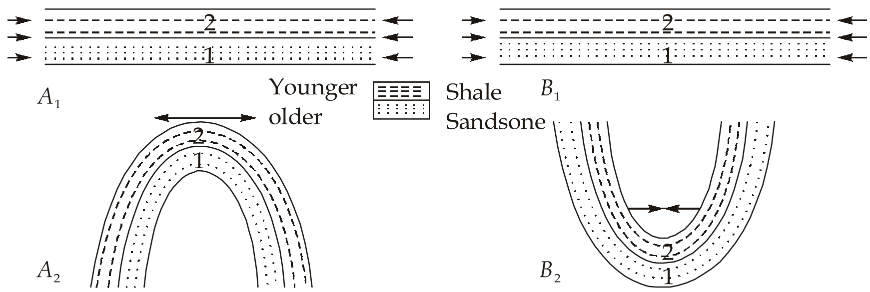
**Synclines:** These folds are the reverse of anticlines in all details and may be described as those folds in which

(i) the strata are downarched, that is, these become CONVEX DOWNWARD;

(ii) the geologically younger rocks occupy a position in the core of the fold and the older rocks form the outer flanks, provided the normal order of superposition is not disturbed,

(iii) in the simplest cases in synclines, the limbs dip towards a common centre.

Symbolically, a syncline may be indicated by two arrows pointing towards a central point, the hinge point.




**Anticline and Syncline (a) and (b) Strata before and after folding**

**20. (b)**

Sum of latitudes, $\Sigma L = \Sigma\text{Northing} - \Sigma\text{Southing}$

$= 30.77 + 202.16 - (158.11 + 75.28) = -0.46$ m

Sum of departures, $\Sigma D = \Sigma\text{Easting} - \Sigma\text{Westing}$

$= (153.44 + 82.19) - (222.4 + 13.25)$

$= -0.02$ m

As the latitude and departure both are negative, the closing error lies in the S-W quadrant.

**21. (a)**

As the distance to the staff at $P$ is only 80 m, the correction for curvature and refraction is very small for the reading on $P$. However, the reading on the staff at $Q$ has to be corrected, as the distance is large, (1520 m).

$\therefore$ Corrected staff reading on $Q = 2.735 - 0.0673(1.52)^2$

$= 2.735 - 0.155 = 2.580$ m

$\therefore$ True difference of elevation $= 2.580 - 0.785$

$= 1.795$ m

**22. (d)**

The following errors are eliminated by method of repetition:

1. Errors due to eccentricity of verniers and centres are eliminated by taking both vernier readings.
2. Errors due to incorrect adjustments of line of collimation and the trunnion axis are eliminated by taking both face readings.
3. The error due to inaccurate graduations are eliminated by taking the readings at different parts of the circle.

**23. (c)**

| Staff station | BS (m) | IS (m) | FS (m) | HI (m) | RL (m) | Remarks |
|---|---|---|---|---|---|---|
| P | 1.785 | | | 101.785 | 100 | BM |
| Q | | 2.065 | | | 99.72 | |
| R | | | 1.315 | | 100.47 | |

From table above

$$\text{RL of R} = 100.47 \text{ m}$$

Formula used: $\text{H.I} = \text{RL of BM + BS}$

$\therefore$ $\text{RL of any point} = \text{H.I} - \text{(IS/FS) reading}$

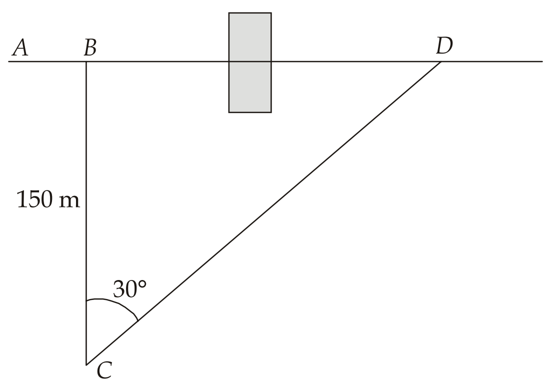
**24. (c)**

**Bowditch's method:**

- The basis of this method is the assumption that the error in linear measurements are proportional to $\sqrt{l}$, and that error in angular measurements are inversely proportional to $\sqrt{l}$.
- It is mostly used to balance a traverse where linear and angular measurements are of equal precision.
- The total error in latitude and in the departure is distributed in proportion to the length of the sides.

Hence, statements 1 and 4 are the correct statements.

**25. (b)**




From $\Delta BCD$

$$CD = \frac{BC}{\cos 30°}$$

$$\Rightarrow \quad CD = \frac{150}{\cos 30°} = \frac{300}{\sqrt{3}} \text{ m}$$

$$BD = \sqrt{CD^2 - BC^2}$$

$$\Rightarrow \quad BD = \sqrt{\left(\frac{300}{\sqrt{3}}\right)^2 - (150)^2}$$

$$= \sqrt{(150)^2\left(\frac{2}{\sqrt{3}}\right)^2 - 1}$$

$$= 150\sqrt{\frac{4}{3} - 1} = 150 \times \frac{1}{\sqrt{3}} = 86.6 \text{ m}$$

$\therefore$ Chainage of $D$ = Chainage of B + BD

$= 240 + 86.6$

$= 326.6$ m

**26.** **(d)**

Archaeological surveys are conducted to locate relics of antiquity, civilizations etc.

**27.** **(c)**

The diurnal variation or daily variation is the systematic departure of the declination from its mean value during a period of 24 hrs. The extent of daily variations depend upon the following factors:

1. **The locality**: More at magnetic poles and less at equator.
2. **Season of the year**: Considerably more in summer than in winter.
3. **Time**: More in day and less in night.

**28.** **(a)**

By inspection of the observed bearings, it is noticed that stations *C* and *D* are free from local attractions since the *BB* and *FB* of *CD* differ exactly by 180°. All the bearings measured at *C* and *D* are, therefore correct.

Thus, the observed back bearing of *BC* of 296° 35′ is correct.

$\therefore$ Correct bearing of $BC$ = 296° 35′ – 180° = 116°35′

Observed fore bearing of $BC$ = 115°20′

$\therefore$ Correction at station $B$ = 116°35′ – 115° 20′

= +1° 15′

$\therefore$ Correct back bearing of $AB$ = 254° 20′ + 1°15′

= 255° 35′ = Correct bearing of line $BA$

**29.** **(c)**

From tacheometric equation, $D = kS + C$

$C$ = Additive constant

$= f + d = 24 + 16 = 40$ cm

Staff intercept, $S = 2.055 - 1.460 = 0.595$ m

$\therefore \quad 60 = k \times 0.595 + 0.4$

$$\Rightarrow \quad k = \frac{59.6}{0.595} = 100.168 \simeq 100.17$$

$$\therefore \quad \frac{f}{i} = 100.17$$

$$\Rightarrow \quad i = \frac{24 \times 10}{100.17} \simeq 2.4 \text{ mm}$$

**30.** **(d)**

Given: Focal length of camera, $f = 160$ mm

Flying height above MSL, $H = 1600$ m

$$S_{\text{datum}} = \frac{f}{H} = \frac{160}{1600 \times 1000}$$

$$= \frac{1}{10000}$$

$\Rightarrow \quad 1 \text{ cm} = 100 \text{ m}$

∴ Length of air base, $B = 9.375 \times 100 = 937.5$ m

$$p_{top} = \frac{Bf}{H - h_{top}}$$

$$= \frac{937.5 \times 160}{1600 - 120} = 101.35 \text{ mm}$$

$$p_{bottom} = \frac{Bf}{H - h_{bottom}}$$

$$= \frac{937.5 \times 160}{1600} = 93.75 \text{ mm}$$

∴ Difference of parallax, $\Delta P = p_{top} - p_{bottom}$
$= 101.35 - 93.75 = 7.6$ mm

**31. (b)**

- Isocentre is the point at which the bisector of the angle of tilt meets the photograph.
- Nadir point is a point on the photograph vertically beneath the exposure station.
- On a vertical photograph, the isocentre and the photo-nadir point coincide with the principal point.

**32. (c)**

Length of long chord, $L = 2R\sin\frac{\Delta}{2}$

⇒ $120 = 2R\sin\left(\frac{60°}{2}\right)$

⇒ $R = \frac{60}{\sin 30°} = 120 \text{ m}$

∴ Tangent length $= R\tan\frac{\Delta}{2} = 120\tan\left(\frac{60°}{2}\right)$
$= 120 \times \tan(30°) = 69.282$ m

**33. (a)**

From planimeter readings, the area is given by:

Area $= M[FR - IR \pm 10N + C]$

Given: $FR = 2.921$; IR = 6.973;
$N = +1$ and $C = 0$ (For the anchor point inside)

∴ Area $= 100[2.921 - 6.973 + 10]$
$= 594.8 \text{ cm}^2$

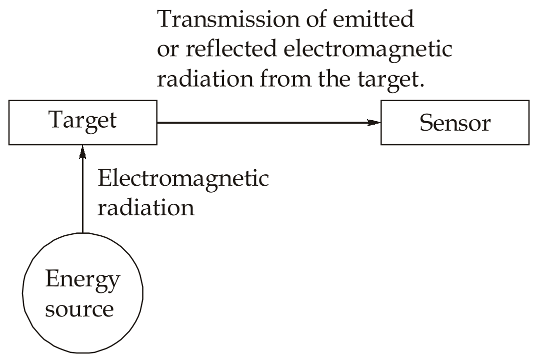
Scale, 1 cm = 100 m

Area of the ground $= 594.8 \times (100)^2 \text{ m}^2$

$$= \frac{594.8 \times 10^4}{10^4} \text{ ha} = 594.8 \text{ ha}$$

**34. (d)**

Components of a remote sensing system:




**35. (a)**

Consider a 20 m chain, which is 20 cm too short.

When the chain is laid out straight, we are actually measuring a length of 19.8 m only, which is the actual length of the chain. However, it is recorded as 20 m. Thus, with a shorter chain, the error has to be deducted or the error is positive and the correction is negative.

**36. (d)**

The contour interval largely depends upon the purpose and the extent of the survey.

For example, if the survey is intended for detailed design work or for accurate earthwork calculations, small contour interval is to be used. The extent of survey in such cases will be generally small. In the case of location surveys, for lines of communications and for reservoir and drainage areas, where the extent of survey is large, a large contour interval is used.

**38. (a)**

The possibility of block shear failure increases with the use of high bearing strength material and high strength bolts which results in fewer bolts and smaller connection length.

**39. (a)**

The deformation of uniformly tapering rectangular bar is given by

$$\Delta = \frac{Pl}{(b_2 - b_1)tE}\ln\frac{b_2}{b_1}$$

Here,

$$P = 200 \text{ kN}$$
$$l = 400 \text{ mm}$$
$$b_2 = 80 \text{ mm}$$
$$b_1 = 20 \text{ mm}$$
$$t = 20 \text{ mm}$$
$$E = 2 \times 10^5 \text{ MPa}$$

$\therefore$

$$\Delta = \frac{200 \times 10^3 \times 400}{(80-20)20 \times 2 \times 10^5}\ln\left(\frac{80}{20}\right)$$

$$\Delta = \frac{200 \times 10^3 \times 400}{60 \times 20 \times 2 \times 10^5}\ln 4 = 0.46 \text{ mm}$$

**40. (b)**

$$\text{Area of shaft section} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 140 \times 140 \text{ mm}^2$$

$$\text{Compressive stress in shaft,} \quad \sigma_c = \frac{660 \times 10^3}{\frac{\pi}{4} \times 140 \times 140}$$

$$\text{Shear area of the collar} = \pi \times d \times h$$

$$= \pi \times 140 \times 21 \text{ mm}^2$$

$$\text{Shear stress in collar,} \quad \tau_c = \frac{660 \times 10^3}{\pi \times 140 \times 21}$$

$$\therefore \text{ Ratio,} \quad \frac{\sigma_c}{\tau_c} = \frac{\dfrac{660 \times 10^3}{\frac{\pi}{4} \times 140 \times 140}}{\dfrac{660 \times 10^3}{\pi \times 140 \times 21}}$$

$$= \frac{\pi \times 140 \times 21}{\frac{\pi}{4} \times 140 \times 140}$$

$$= \frac{4 \times 21}{140} = \frac{84}{140} = 0.6$$

**41. (c)**

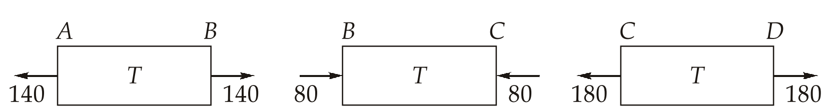
Resolving the forces on the rod along its axis, we have

$$P_1 + P_3 = P_2 + P_4$$

$$\Rightarrow \quad 140 + P_3 = 220 + 180$$

$$\Rightarrow \quad P_3 = 260 \text{ kN}$$

Force distribution



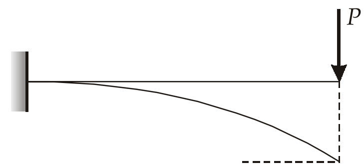

$$\delta_{BC} = \frac{P_{BC} L_{BC}}{A_{BC} E_{BC}} = \frac{80 \times 10^3 \times 1000}{25 \times 25 \times E} = \frac{128000}{E}$$

**42. (d)**

$$\text{Force on the shaded area,} \quad F = \frac{f_{\max}}{y_{\max}} A\bar{y}$$

$$= \frac{10}{120} \times \left[\frac{1}{2} \times 120 \times 150 \times \frac{2}{3} \times 120\right] \text{N} = 60 \text{ kN}$$

**43. (b)**




At, fixed end slope = 0.

1. Bending stress at free end is zero.

2. $\tau_{max} = f(\tau_{avg})$ and $\tau_{avg} = \dfrac{V}{\text{Cross-sectional Area}}$

Here $V = \text{constant } (= P)$

Hence $\tau_{max} = \text{constant}$

**44. (b)**

Original volume, $V = \dfrac{\pi}{4} d^2 l$

By partial differentiation $\delta V = \dfrac{\pi}{4} l\{2d(\delta d)\} + \dfrac{\pi}{4} d^2 (\delta l)$

$$\frac{\delta V}{V} = \frac{\delta l}{l} + \frac{2\delta d}{d}$$

$$= \frac{pd}{4tE}(1-2\mu) + 2 \times \frac{pd}{4tE}(2-\mu) = \frac{pd}{4tE}(5-4\mu)$$

**45. (b)**

$$G = 80 \text{ GPa}$$

$$K = 160 \text{ GPa}$$

$$E = \frac{9KG}{3K+G}$$

$\Rightarrow$ $$E = \frac{9 \times 160 \times 80}{3 \times 160 + 80} = 205.71 \text{GPa} \simeq 205 \text{ GPa}$$

$$\mu = \frac{3K-2G}{6K+2G}$$

$$= \frac{3 \times 160 - 2 \times 80}{6 \times 160 + 2 \times 80}$$

$$= \frac{480-160}{960+160} = \frac{320}{1120} = 0.286 \simeq 0.28$$

**47. (c)**

- Diagram A $\rightarrow$ Only shear stress is acting i.e. circular shaft subjected to torsion.
- Diagram B $\rightarrow$ Only tensile stress is acting i.e. tie bar is subjected to tensile force.
- Diagram C $\rightarrow$ Hoop stress and longitudinal stress are acting.
- Diagram D $\rightarrow$ Shear stress as well as normal stress are acting therefore circular shaft is subjected to combined bending and torsion.

**48. (a)**

For plastic deformation, $\mu = 0.5$

$\sigma_1 = 30 \text{ kg/mm}^2, \sigma_2 = 10 \text{ kg/mm}^2, \sigma_3 = 5 \text{ kg/mm}^2$

Principal strain, $$\epsilon_1 = \frac{\sigma_1}{E} - \frac{\mu(\sigma_2 + \sigma_3)}{E}$$

$$\Rightarrow \quad \epsilon_1 = \frac{30}{E} - \frac{0.5}{E}(10+5)$$

$$\Rightarrow \quad \epsilon_1 = \frac{30}{E} - \frac{7.5}{E} = \frac{22.5}{E}$$

$$\epsilon_2 = \frac{10}{E} - \frac{0.5}{E}(30+5)$$

$$= \frac{10}{E} - \frac{17.5}{E} = \frac{-7.5}{E}$$

$$\epsilon_3 = \frac{5}{E} - \frac{0.5}{E}(30+10) = \frac{5}{E} - \frac{20}{E} = -\frac{15}{E}$$

$$\therefore \quad \epsilon_1 : \epsilon_2 : \epsilon_3 = 22.5 : -7.5 : -15 = 3 : (-1) : (-2)$$

$$= 15 : (-5) : (-10)$$

**49. (d)**

$\sigma_1 = 12 \text{ kPa}, \sigma_y = 0, \sigma_x = 10 \text{ kPa}$

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\Rightarrow \quad 12 = \frac{10+0}{2} + \sqrt{\left(\frac{10-0}{2}\right)^2 + \tau_{xy}^2}$$

$$\Rightarrow \quad 12 = 5 + \sqrt{25 + \tau_{xy}^2}$$

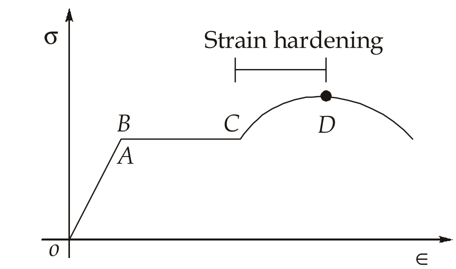
$$\Rightarrow \quad 7 = \sqrt{25 + \tau_{xy}^2}$$

$$\Rightarrow \quad 49 = 25 + \tau_{xy}^2$$

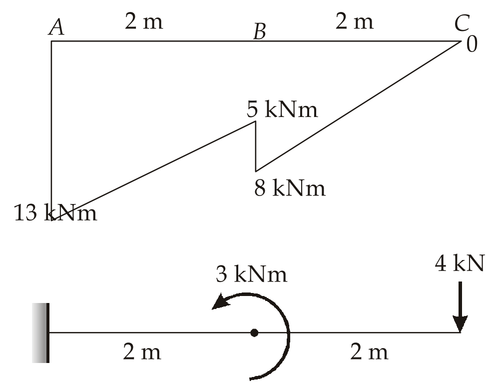
$$\Rightarrow \quad \tau_{xy}^2 = 49 - 25 = 24$$

$$\Rightarrow \quad \tau_{xy} = \sqrt{24} = 2\sqrt{6} \text{ kPa}$$

**51. (b)**




**52. (a)**



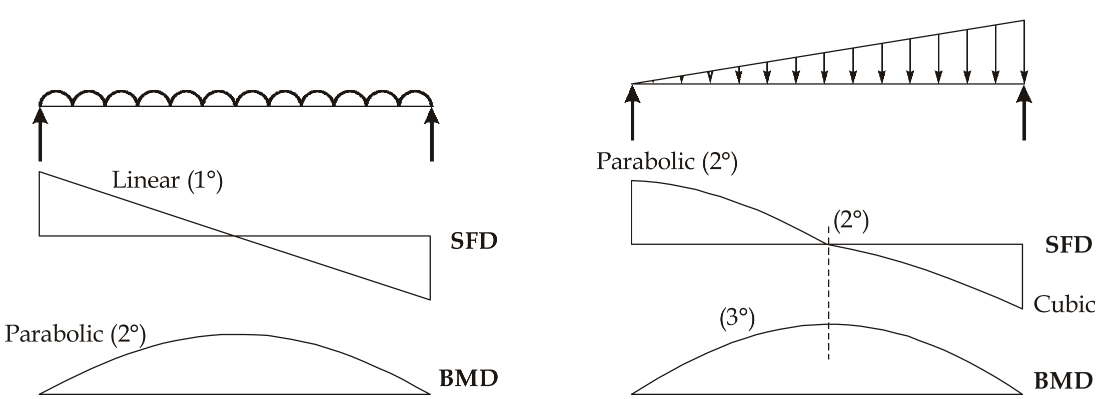

Possible cases of ratio of loadings are:

(i) $\frac{3}{4} = 0.75$ (ii) $\frac{4}{3} = 1.33$

**53. (d)**

1. Linear BMD indicates constant SFD.
2. Sudden change in sign of BMD indicates a couple.

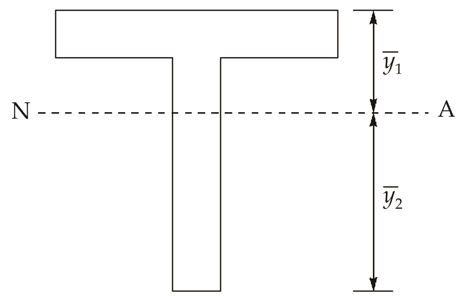
**54. (d)**



**55. (c)**

Generally, a beam of constant cross-section throughout the length is provided, this given rise of constant section modulus and has constant or uniform MOR. The actual moment generally varies along the length, such section is not economical therefore we use a beam of variable section designed to have uniform strength.

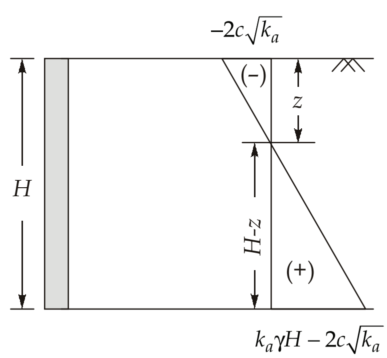
**56. (d)**




Here NA is near to flange area and therefore maximum bending stress would occur at the bottom fibre of the web because

$$\bar{y}_2 > \bar{y}_1$$

**58. (d)**




$$k_a\gamma z - 2c\sqrt{k_a} = 0$$

$$\Rightarrow \quad z = \frac{2c}{\gamma\sqrt{k_a}}$$

After tension cracks get developed, consider the earth pressure due to $(H - z)$ depth only.

$\therefore$ Total active earth pressure, $$P = \frac{1}{2}\times\left(k_a\gamma H - 2c\sqrt{k_a}\right)\times(H - z)$$

$$\Rightarrow \quad P = \frac{1}{2}\times\left(k_a\gamma H - 2c\sqrt{k_a}\right)\times\left(H - \frac{2c}{\gamma\sqrt{k_a}}\right)$$

$$\Rightarrow \quad P = \frac{1}{2}k_a\gamma H^2 - 2cH\sqrt{k_a} + \frac{2c^2}{\gamma}$$

**60. (d)**

Area ratio should not be greater than 20% for stiff formations and 10% for soft sensitive soil.

**61. (c)**

- In pile load test, allowable load is taken as 50% of the load at which settlement equals 10% of pile diameter in case of uniform diameter piles and 7.5% of bulb diameter in case of under reamed piles.
- In pile load test, load on test pile = 2.0 times the allowable load = 2 $Q_{all}$.

Load on working pile = 1.5 times the allowable load = 1.5 $Q_{all.}$

$$\therefore \quad \text{Ratio} = \frac{2.0Q_{\text{all.}}}{1.5Q_{\text{all.}}} = \frac{4}{3}$$

**62. (c)**

$$D_f = 1 \text{ m}$$
$$B = 2 \text{ m}$$
$$\text{UCS} = 20 \text{ kN/m}^2$$
$$\therefore \quad C = \frac{UCS}{2} = 10 \text{ kN/m}^2$$

As per Skemption's theory,

$$N_c = 5\left(1 + 0.2\frac{D_f}{B}\right)$$
$$= 5\left(1 + 0.2\frac{1}{2}\right) = 5.5$$
$$\therefore \quad q_{ns} = cN_c = 10 \times 5.5 = 55 \text{ kN/m}^2$$
$$q_{ns} = \frac{q_{nu}}{FOS}$$
$$= \frac{55}{3} = 18.33 \text{ kN/m}^2$$

**63. (a)**

$$B_p = 0.3 \text{ m}$$
$$B_f = 1.5 \text{ m}$$

For granular soil,

$$\frac{S_f}{S_p} = \left\{\frac{B_f}{B_p}\frac{(B_p + 0.3)}{(B_f + 0.3)}\right\}^2$$
$$\Rightarrow \quad \frac{S_f}{S_p} = \left(\frac{1.5 \times 0.6}{0.3 \times 1.8}\right)^2$$
$$\Rightarrow \quad S_f = \frac{25}{9} \times 18$$
$$\Rightarrow \quad S_f = 50 \text{ mm}$$

**64. (d)**

$$Q_{up} = Q_{eb} + Q_{sf}$$
$$Q_{sf} = \alpha \overline{Cu} \cdot A_s$$
$$= 0.8 \times 40 \times (4 \times 0.5) \times 15 = 960 \text{ kN}$$

**65. (a)**

For a pure clay, $N_c = 5.7, N_q = 1, N_\gamma = 0$

For square footing, $q_u = 1.3\, cN_c + \gamma D_f \cdot N_q + 0.4\, \gamma B N_\gamma$

$$C = \frac{UCS}{2} = \frac{0.15}{2} \text{N/mm}^2 = 0.075 \text{ N/mm}^2 = 75 \text{ kN/m}^2$$
$$\gamma = 1.7 \text{ g/cm}^3$$
$$= 1700 \text{ kg/m}^3$$
$$= \frac{1700 \times 9.81}{1000} \text{kN/m}^3 = 16.68 \text{ kN/m}^3$$
$$q_u = 1.3 \times 75 \times 5.7 + 16.68 \times 2 \times 1 + 0$$
$$q_u = 589.11 \text{ kN/m}^2 \simeq 589 \text{ kN/m}^2$$

**67. (b)**

In the process of photosynthesis, plants produce oxygen which, in the presence of sunlight exceeds the amount of oxygen required for respiration. Thus, DO is maximum at noon.

**68. (a)**

The maximum working area for a landfill can be computed as

$$A_{\max} = \frac{CW}{R}$$

where $C$ = Absorption capacity of waste

$W$ = Average annual waste input

$R$ = Average annual rainfall

Hence, $$A_{\max} = \frac{0.15 \times 12000}{1.8} = 1000 \text{ m}^2$$

**70. (c)**

$$\text{Volume of soak well} = \frac{\text{Outflow}}{\text{Percolation rate}} = \frac{10 \times 10^3 \; l/\text{day}}{1200 \; l/\text{m}^3/\text{day}} = 8.333 \text{ m}^3$$

$$\therefore \quad \text{Area of soak well required} = \frac{8.333}{2} = 4.167 \text{ m}^2$$

$$\therefore \quad \text{Diameter of soak well} = \sqrt{\frac{4.167 \times 4}{\pi}} = 2.3 \text{ m}$$

**72.** **(d)**

Sludge stabilisation converts the energy rich organic substances into low energy compounds by stopping natural fermentation of the sludge.

**73.** **(b)**

1 mole of benzene ($C_6H_6$) = 78 gm benzene

Concentration of benzene = $78 \times 0.002 \times 10^3$ mg/$l$

= 156 mg/$l$

Chemical reaction: $$\underbrace{C_6H_6}_{78} + \underbrace{\frac{15}{2}O_2}_{240} \longrightarrow \underbrace{6CO_2}_{264} + \underbrace{3H_2O}_{54}$$

Theoretical oxygen demand = $\dfrac{240}{78} \times 156 = 480$ mg/$l$

**74.** **(c)**

Vent pipes avoid the building up of pressure in the septic tank and the seepage pit.

**75.** **(c)**

Inner piles should be driven first because if pile driving mechanism starts from the periphery, it would be uneconomical to drive the inner piles into the highly compacted ground.

■■■■