CLASS TEST

S.No. : 01SK_CE_ABCD_210925

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Design of Steel Structures

CIVIL ENGINEERING

Date of Test : 21/09/2025

ANSWER KEY

1.	(d)	7.	(c)	13.	(b)	19.	(a)	25.	(b)
2.	(c)	8.	(a)	14.	(c)	20.	(a)	26.	(b)
3.	(c)	9.	(a)	15.	(a)	21.	(c)	27.	(c)
4.	(d)	10.	(b)	16.	(c)	22.	(b)	28.	(c)
5.	(c)	11.	(a)	17.	(a)	23.	(d)	29.	(a)
6.	(b)	12.	(d)	18.	(a)	24.	(c)	30.	(b)

DETAILED EXPLANATIONS

3. (c)

Maximum slenderness ratio for various types of tension members

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

4. (d)

Design stress for the fillet weld, $f_{wd} = \dfrac{f_u}{\sqrt{3}\gamma_{mw}} = \dfrac{410}{\sqrt{3} \times 1.25} = 189.37\ \text{N/mm}^2$

Design strength of fillet weld per mm length

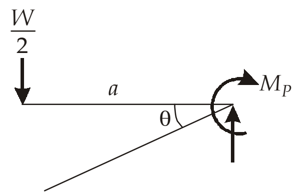
$$= f_{wd} \times 1 \times t_t$$
$$= 189.37 \times 1 \times 0.7 \times 8 = 1060.476$$
$$\simeq 1060.5\text{N/mm}$$

5. (c)

For simultaneous failure, plastic moments of overhang and span *AB* should be same.

∴ By virtual work theorem,

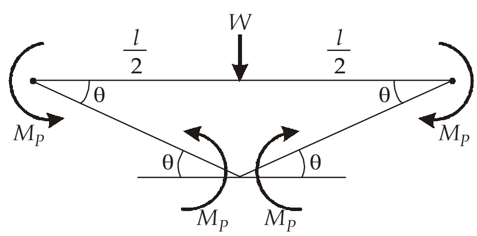
For overhang



$$\frac{W}{2} \times a \times \theta = M_P \times \theta$$

⇒ $$M_P = \frac{Wa}{2} \qquad ...(i)$$

For span *AB*,



$$W \times \frac{l}{2} \times \theta = 4M_P\,\theta$$

$$\Rightarrow \qquad M_p = \frac{Wl}{8} \qquad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{Wa}{2} = \frac{Wl}{8}$$

$$\Rightarrow \qquad a = \frac{l}{4}$$

6. **(b)**

Refer IS 800 : 2007

Clause 8.7.1

7. **(c)**

As per caluse 6.3 of IS 875 : part III 2015

$$\text{Design wind speed, } V_z = k_1 k_2 k_3 k_4 V$$
$$= 1 \times 0.5 \times 0.5 \times 1.15 \times 40$$
$$= 11.5 \text{ m/s}$$

As per clause 7.1 of IS 875 : Part III 2015

$$\text{Design wind pressure} = 0.6 V_z^2$$
$$= 0.6 \times 11.5^2 = 79.35 \text{ N/m}^2$$

9. **(a)**

$$\delta' = \frac{11.62}{U_*}$$

$$u_* = \text{Shear velocity}$$

$$\Rightarrow \qquad u_* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\delta' = \frac{11.62}{\sqrt{\frac{\tau_0}{\rho}}}$$

$$\tau_0 = \text{Wall shear stress}$$
$$\rho = \text{Density of fluid}$$

10. **(b)**

Refer IS 800 : 2007 (Table 2)

(i) $$\frac{b}{t_f} = 6.6 < 8.4\epsilon$$

where $$\epsilon = \sqrt{\frac{250}{f_y}} = 1 \text{ (Given)}$$

$\Rightarrow$ Flange section is plastic (class I)

(ii) $$\frac{d}{t_w} = 89 < 105\epsilon$$

$\Rightarrow$ Web section is compact (Class 2)

$\therefore$ The overall section is considered compact.

11. (a)

Channels are placed back to back such that $(I_{zz})_{combined} = (I_{yy})_{combined}$.

C_{yy}

I_{zz} S $(I_{zz})_{co}$

I_{yy} $(I_{yy})_{co}$ I_{yy}

$$\therefore \quad 2I_{zz} = 2\left[I_{yy} + A\left(\frac{S}{2}+C_{yy}\right)^2\right]$$

$$\Rightarrow \quad 2 \times 6321 \times 10^4 = 2\left[310\times10^4 + 4564\times\left(\frac{S}{2}+23.6\right)^2\right]$$

$$\Rightarrow \quad S = 182.325 \text{ mm} \simeq 182.3 \text{ mm}$$

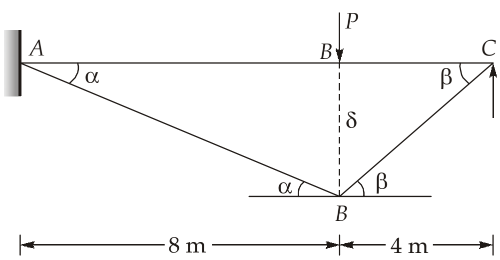
12. (d)

$$D_s = 2 + 1 - 2 = 1$$

No. of hinges required for mechanism formation

$$= D_s + 1 = 1 + 1 = 2$$

Mechanism is as shown below (plastic hinges at A and B)



From diagram
$8\alpha = 4\beta$
$2\alpha = \beta$

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

$$\Rightarrow \quad P \times \delta = M_P\alpha + M_P\alpha + M_P\beta$$

$$\Rightarrow \quad P \times \delta = 2M_P\alpha + M_P\beta$$

$$\Rightarrow \quad P \times \delta = 2M_P\beta$$

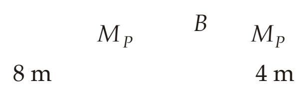
$$\Rightarrow \qquad P \times \delta = 2M_P \times \frac{\delta}{4}$$

$$\Rightarrow \qquad P = \frac{M_P}{2}$$

$$\Rightarrow \qquad P = \frac{180}{2} = 90 \text{ kN}$$

$\therefore$ Collapse load = 90 kN

Now, $\Sigma M_A = 0$



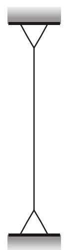
$$\therefore \quad M_P - M_P + M_P + R \times 12 = 90 \times 8$$

$$\Rightarrow \qquad 180 + R \times 12 = 720$$

$$\Rightarrow \qquad R = 45 \text{ kN}$$

13. (b)

Non dimensional effective slenderness ratio is given by



$$\lambda = \sqrt{\frac{f_y}{f_{cc}}}$$

$$f_{cc} = \frac{\pi^2 E}{\left(\frac{kL}{r}\right)^2}$$

$$kL = 1 \times 7000 \text{ mm} = 7000 \text{ mm}$$

($\because$ Column is hinged at both the ends)

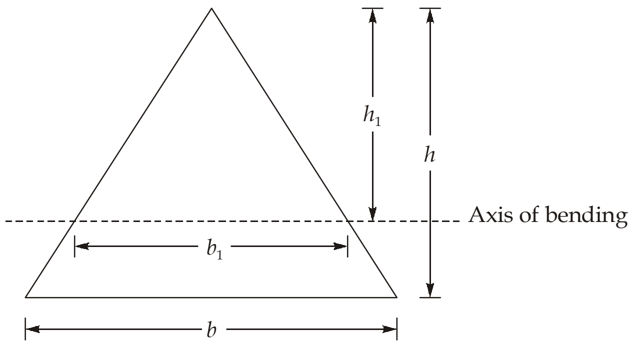
$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{13533 \times 10^4}{28000}}$$

$$\Rightarrow \qquad r = 69.521 \text{ mm}$$

$$f_{cc} = \frac{\pi^2 \times 2 \times 10^5}{\left(\frac{7000}{69.521}\right)^2} = 194.699 \simeq 194.7 \text{ N/mm}^2$$

$$\therefore \qquad \lambda = \sqrt{\frac{250}{194.7}} = 1.133 \simeq 1.13$$

14. (c)



From similar triangles, $$\frac{b_1}{b} = \frac{h_1}{h} \quad \text{...(i)}$$

Plastic neutral axis divides the section into two equal areas.

$$\therefore \quad \frac{1}{2}\left(\frac{1}{2}\times b\times h\right) = \frac{1}{2}\times b_1 h_1$$

$$\Rightarrow \quad b_1 h_1 = \frac{bh}{2} \quad \text{...(ii)}$$

Using eq. (i) and eq. (ii)

$$b_1 = \frac{b}{\sqrt{2}} \text{ and } h_1 = \frac{h}{\sqrt{2}}$$

$$Z_p = \frac{A}{2}[\bar{y}_c + \bar{y}_t]$$

$$\bar{y}_c = \left(\frac{h}{\sqrt{2}}\right)\frac{1}{3}$$

Compression

h $\quad$ $\frac{h}{2}$

$b/2$ $\quad$ y_t $\quad$ Tension

b

$$\bar{y}_t = \frac{2b+\frac{b}{\sqrt{2}}}{b+\frac{b}{\sqrt{2}}}\times\left(\frac{h-\frac{h}{\sqrt{2}}}{3}\right) \quad \text{[Trapezoidal tension section]}$$

$$\Rightarrow \quad \bar{y}_t = \frac{2\sqrt{2}+1}{\sqrt{2}+1}\times\frac{(\sqrt{2}-1)h}{3\sqrt{2}}$$

$$\therefore \quad Z_p = \frac{1}{2}\times\left(\frac{1}{2}bh\right)\left[\frac{h}{3\sqrt{2}}+\frac{2\sqrt{2}+1}{\sqrt{2}+1}\times\frac{(\sqrt{2}-1)h}{3\sqrt{2}}\right]$$

$$\Rightarrow \quad Z_p = \frac{bh^2}{3\sqrt{2}(\sqrt{2}+1)}\times\frac{\sqrt{2}-1}{\sqrt{2}-1}$$

$$\Rightarrow \quad Z_p = \frac{bh^2(\sqrt{2}-1)}{3\sqrt{2}}$$

Given, $b = 20$ cm, $h = 5$ cm

$$\therefore \quad Z_p = \frac{20\times 5^2(\sqrt{2}-1)}{3\sqrt{2}} = 48.816 \text{ cm}^3 \simeq 48.82 \text{ cm}^3$$

15. (a)

Given, M20 bolts of grade 4.6,

Given: $d = 20$ mm, $f_{ub} = 400$ N/mm^2; $f_{yb} = 240$ N/mm^2.

In this connection, packing plate of 8 mm thickness is to be used and hence there shall be reduction in the shear strength of bolt where the reduction factor is

$$\beta_{pkg} = (1 - 0.0125\, t_{pkg})$$
$$= (1 - 0.0125 \times 8) = 0.9$$

∴ Here, connection is double cover butt joint, hence bolts will be in double shear,

For one bolt,

∴ Design shear strength of bolt, $$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\times\gamma_{mb}}(1\times A_{sb}+1\times A_{nb})\times\beta_{pkg}$$

$$= \frac{400}{\sqrt{3}\times 1.25}\left(1\times\frac{\pi}{4}\times 20^2+0.78\times\frac{\pi}{4}\times 20^2\right)\times 0.9\times 10^{-3} \text{ kN}$$

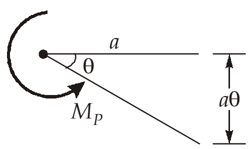
$$= 92.98 \text{ kN} \simeq 93 \text{ kN}$$

∴ Design shear strength of 6 bolts in the joint = 6 × 93 = 558 kN

16. (c)

For simultaneous collapse condition, the plastic hinges shall be formed at A, B and between A and B.

For collapse of part BC

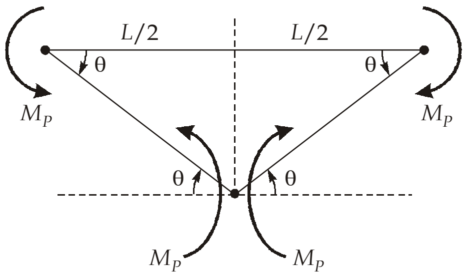


$$W_i = W_E$$

$$\Rightarrow \quad M_p\theta = w_u\left(\frac{1}{2}\times a\times a\theta\right)$$

$$\Rightarrow \quad w_u = \frac{2M_P}{a^2} \quad \text{... (i)}$$

For collapse of part AB, plastic hinges will be developed at A, B and at mid point of AB.



$$W_i = W_E$$

$$\Rightarrow \quad 4M_p\theta = w_u\left(\frac{1}{2}\times L\times\frac{L}{2}\theta\right)$$

$$\Rightarrow \quad w_u = \frac{16M_P}{L^2}$$

For simultaneous collapse of AB and BC ,

$$\frac{2M_P}{a^2} = \frac{16M_P}{L^2}$$

$$\Rightarrow \quad a^2 = \frac{L^2}{8}$$

$$\Rightarrow \quad a = \frac{L}{2\sqrt{2}}$$

17. (a)

Throat thickness of weld, $t_t = ks = 0.7 \times 8 = 5.6$ mm

Strength of fillet weld, $P_{dw} = \frac{f_u}{\sqrt{3}\gamma_{mw}}\times L_w\times t_t$

For connection to be safe, $P_{dw} = P_u$

$$\Rightarrow \quad \frac{410}{\sqrt{3}\times 1.5}\times L_w\times 5.6 = 300\times 10^3$$

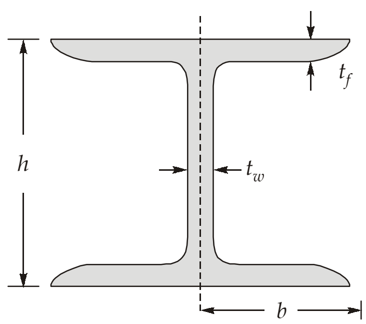
$$\Rightarrow \quad L_w = 339.469 \text{ mm}$$

$$\Rightarrow \quad 2x + 200 = 339.469$$

$$\Rightarrow \quad x = \frac{139.469}{2} = 69.73 \text{ mm} \simeq 70 \text{ mm}$$

18. (a)

Classification of beam section:



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

$$d = h - 2\,(t_f + R_1)$$

$$= 350 - 2\,(14.2 + 14) = 293.6 \text{ mm}$$

$$\frac{b}{t_f} = \frac{140/2}{14.2} = 4.93 < 9.4\varepsilon \;\therefore\; \text{Flange is plastic}$$

$$\frac{d}{t_w} = \frac{293.6}{8.1} = 36.25 < 84\varepsilon \;\therefore\; \text{Web is plastic}$$

Hence section is plastic.

Design bending strength, $M_d = \beta_b \times Z_{pz} \times \frac{f_y}{\gamma_{m0}}$

where β_b = 1 for plastic section

$$= 1.0 \times 889.57 \times 10^3 \times \frac{250}{1.1} \times 10^{-6} \text{ kNm}$$

$$= 202.175 \text{ kNm} \simeq 202.2 \text{ kNm}$$

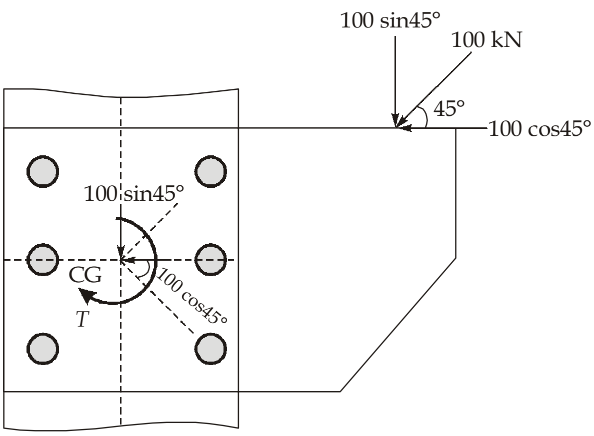
$$\leq 1.2 \times Z_{ez} \times \frac{f_y}{\gamma_{m0}}$$

$$= 1.2 \times 778.9 \times 10^3 \times \frac{250}{1.1} \times 10^{-6} \text{ kNm}$$

$$= 212.427 \text{ kNm} \quad \text{(OK)}$$

Hence, the design bending strength = 202.2 kNm

19. (a)

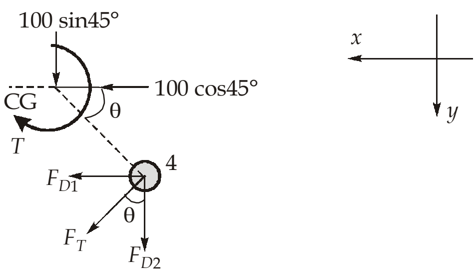


$$\sin\theta = \frac{100}{125}, \cos\theta = \frac{75}{125}$$

$$r_4 = \sqrt{75^2 + 100^2} = 125 \text{ mm}$$

$$\Sigma r_i^2 = 4(125)^2 + 2(75)^2$$

$$= 73750 \text{ mm}^2$$



$$T = 100 \sin 45° \times 0.37 - 100 \cos 45° \times 0.13$$

$$= 16.97 \text{ kN-m}$$

Direct shear force in bolt '4'

$$F_{D1} = \frac{100\cos 45°}{6} = 11.785 \text{ kN}$$

$$F_{D2} = \frac{100\sin 45°}{6} = 11.785 \text{ kN}$$

Torsional shear force in bolt '4'

$$F_T = \frac{Tr_i}{\Sigma r_i^2} = \frac{16.97 \times 10^3 \times 125}{73750} = 28.76 \text{ kN}$$

$$\therefore \quad F_x = F_{D1} + F_T \sin\theta$$

$$= 11.785 + 28.76 \times \frac{100}{125} = 34.793 \text{ kN}$$

$$F_y = F_{D1} + F_T \cos\theta$$

$$= 11.785 + 28.76 \times \frac{75}{125} = 29.041 \text{ kN}$$

$$\therefore \text{Resultant force in bolt 4} = \sqrt{F_x^2 + F_y^2} = \sqrt{(34.793)^2 + (29.041)^2}$$

$$= 45.32 \text{ kN}$$

20. **(a)**

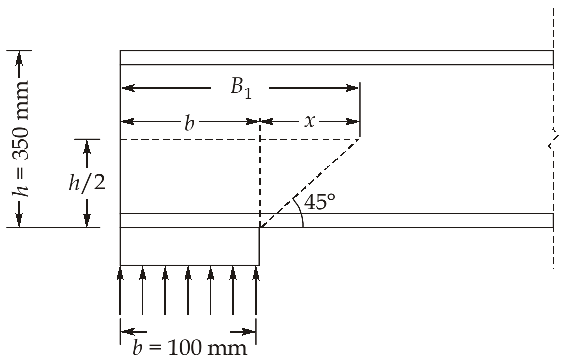
Depth of web: $d = h - 2\,(t_f + R_1)$

$$= 350 - 2\,(11.2 + 16)$$

$$= 295.2 \text{ mm}$$

Slenderness ratio, $\left(\frac{kL}{r}\right) = 2.5\frac{d}{t_w} = 2.5 \times \frac{29.52}{7.4} = 99.73$

From table given: $f_{cd} = 121 + \frac{107 - 121}{100 - 90}(99.73 - 90) = 107.38 \text{ N/mm}^2$



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

$\therefore$ Web buckling strength, $F_{wb} = B_1 \times t_w \times f_{cd}$

$$= 275 \times 7.4 \times 107.38 \times 10^{-3} \text{ kN}$$

$$= 218.52 \text{ kN}$$

21. **(c)**

Diameter of bolt. $d = 20$ mm

Diameter of bolt hole, $d_o = 22$ mm

For Fe410 grade steel, $f_y = 250\ \text{N/mm}^2$

$f_u = 410\ \text{N/mm}^2$

Partial safety factor, $\gamma_{m1} = 1.25$

$\gamma_{m0} = 1.1$

$$\text{Block shear strength, } T_{db} = \min \begin{cases} \dfrac{A_{vg} f_y}{\sqrt{3} \times \gamma_{m0}} + \dfrac{0.9 A_{tn} f_u}{\gamma_{m1}} \\ \dfrac{0.9 A_{vn} f_u}{\sqrt{3} \times \gamma_{m1}} + \dfrac{f_y}{\gamma_{m0}} A_{tg} \end{cases}$$

From figure:

$$A_{vg} = 250 \times 10 = 2500\ \text{mm}^2$$

$$A_{vn} = \left(250 - 2 \times 22 - \frac{22}{2}\right) \times 10 = 1950\ \text{mm}^2$$

$$A_{tg} = 50 \times 10 = 500\ \text{mm}^2$$

$$A_{tn} = \left(50 - \frac{22}{2}\right) \times 10 = 390\ \text{mm}^2$$

$$\therefore \quad T_{db} = \min \begin{cases} \left(\dfrac{2500 \times 250}{\sqrt{3} \times 1.1} + \dfrac{0.9 \times 390 \times 410}{1.25}\right) \times 10^{-3} \\ \left(\dfrac{0.9 \times 1950 \times 410}{\sqrt{3} \times 1.25} + \dfrac{250}{1.1} \times 500\right) \times 10^{-3} \end{cases}$$

$$= \min \begin{cases} 443.17\ \text{kN} \\ 445.98\ \text{kN} \end{cases} = 443.17\ \text{kN}$$

22. **(b)**

Shear force in the weld per unit length,

$$q_w = \frac{V \times A_f \times \bar{y}}{2 I_z}$$

($\because$ There will be two weld lengths along the span for each flange to web connection)

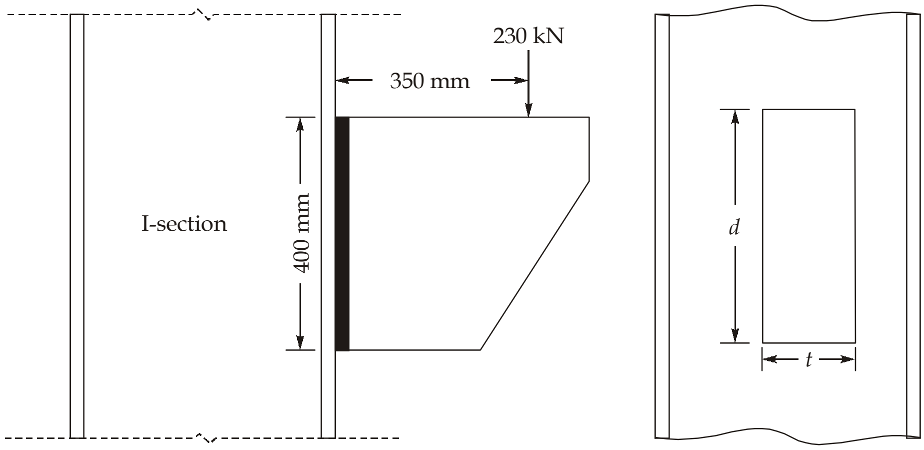
$$I_{zz} = \frac{b_f \times D^3}{12} - \frac{(b_f - t_w) \times d^3}{12}$$

$$= \frac{560 \times 1900^3}{12} - \frac{(560 - 16) \times 1800^3}{12} = 5.57 \times 10^{10}\ \text{mm}^4$$

$$\therefore \quad q_w = \frac{1908 \times 560 \times 50 \times \left(900 + \dfrac{50}{2}\right)}{2 \times 5.57 \times 10^{10}}$$

$$= 0.4436\ \text{kN/mm} \simeq 0.444\ \text{kN/m}$$

23. (d)



d = 400 mm, t = 16 mm

Direct shear stress, $$q = \frac{P}{t \times d} = \frac{230 \times 10^3}{16 \times 400} = 35.94 \text{ N/mm}^2$$

Bending stress, $$f_b = \frac{M}{I} y = \frac{Pe}{\left(\frac{td^3}{12}\right)} \times \frac{d}{2}$$

$$= \frac{6Pe}{td^2} = \frac{6 \times 230 \times 10^3 \times 350}{16 \times (400)^2} = 188.67 \text{ N/mm}^2$$

Resultant stress, $$f_r = \sqrt{f_b^2 + 3q^2} = \sqrt{(188.67)^2 + 3(35.94)^2}$$

$$= 198.674 \text{ N/mm}^2 \le \frac{f_y}{\gamma_{m0}} = \frac{250}{1.1} = 227.27 \text{ N/mm}^2 \qquad \text{(OK)}$$

24. (c)

$\because$ $$\text{S.F.} = \frac{Z_P}{Z_e}$$

Moment of inertia, $$I = \frac{18 \times 30^3}{12} - \left[\frac{6 \times 6^3}{12} + 6 \times 6 \times 6^2\right] \times 2$$

$$= 37692 \text{ mm}^4$$

$$y_{max} = 15 \text{ mm}$$

$\therefore$ $$Z_e = \frac{I}{y_{max}} = \frac{37692}{15} = 2512.8 \text{ mm}^3$$

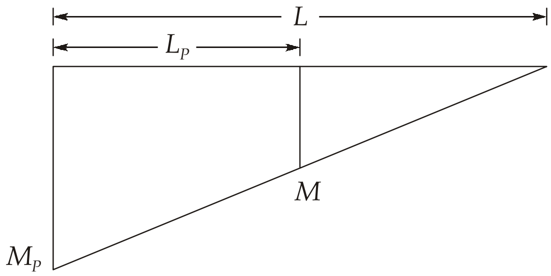
$\therefore$ $$Z_p = \frac{A}{2}(\bar{y}_1 + \bar{y}_2) = A_1 y_1 + A_2 y_2$$

$$= 2 \times [18 \times 15 \times 7.5 - 6 \times 6 \times 6]$$

$$= 3618 \text{ mm}^3$$

$\therefore$ $$\text{S.F.} = \frac{Z_P}{Z_e} = \frac{3618}{2512.8} = 1.4398 \simeq 1.44$$

25. (b)



We know, $$f = \frac{M_p}{M} = \frac{L}{L - L_p}$$

$$\Rightarrow \quad \frac{1}{f} = \frac{L - L_p}{L} = 1 - \frac{L_p}{L}$$

$$\Rightarrow \quad L_p = \left(1 - \frac{1}{f}\right)L = \left(1 - \frac{1}{1.5}\right)L = \left(1 - \frac{2}{3}\right)L = \frac{L}{3}$$

26. (b)

(a) Strength from consideration of yielding

$$T_{dg} = \frac{A_g f_y}{\gamma_{mo}} = \frac{160 \times 8 \times 250}{1.1} \text{N}$$

$= 290909$ N $= 290.909$ kN $\simeq 290.91$ kN

(b) Strength from the consideration of rupture along the critical section

$$A_n = \left[b - nd_o + \frac{\Sigma P_{si}^2}{4g_i}\right]t$$

$b = 160$ mm, $d_0 = 16 + 2 = 18$ mm, $P_{si} = 40$ mm, $g_i = 25$ mm

Critical section along section 1-1-1-1-1

$$A_n = (160 - 3 \times 18) \times 8 = 848 \text{ mm}^2$$

$$\therefore \quad T_{dn} = \frac{0.9 A_n f_u}{\gamma_{ml}} = \frac{0.9 \times 848 \times 410}{1.25} \text{ N} = 250.330 \text{ kN}$$

So, strength of plate = minimum of (a) and (b) i.e., 250.33 kN

27. (c)

Throat thickness of weld, $t_t = 0.7$ s

$= 0.7 \times 8 = 5.6$ mm

Design stress in weld, $$f_{wd} = \frac{f_u}{\sqrt{3}\,\gamma_{mw}} = \frac{410}{\sqrt{3} \times 1.25} = 189.4 \text{ N/mm}^2$$

Design strength of weld per mm length of cylinder

$= 2 \times 189.4 \times 1 \times 5.6$

$= 2121.28$ N/mm

Let P_d = Design fluid pressure inside the cylinder

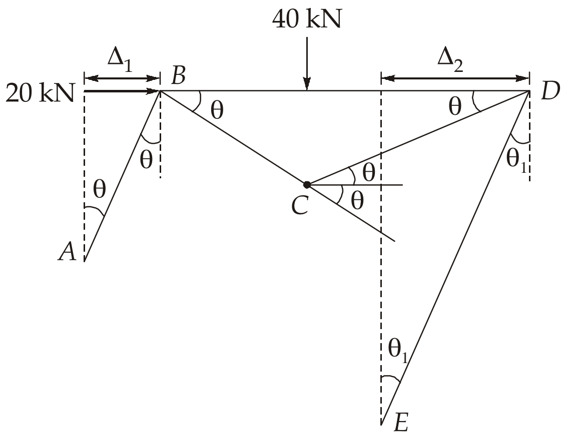
Design hoop tension/pressure per mm length of cylinder

$$\Rightarrow \quad P_d \frac{D}{2} = \frac{P_d \times 500}{2} = 2121.28$$

$$\Rightarrow \quad P_d = 8.48 \text{ N/mm}^2$$

28. (c)

Combined mechanism: The possible location of plastic hinges are *A*, *C*, *D* and *E* only.



$$\Delta_1 = \Delta_2$$

$$\Rightarrow \quad 3\theta = 6\theta_1$$

$$\Rightarrow \quad \theta = 2\theta_1$$

External work done = Σ load × Deflection

$= 40 \times 2\theta + 20 + 3\theta$

$= 140\theta$

Internal work done = Σ plastic moment × Rotation

$= M_p\theta + 2M_p\theta + M_p\theta + M_p\theta_1 + M_p\theta_1$

$= M_p\theta + 2M_p\theta + M_p\theta + \frac{M_p\theta}{2} + \frac{M_p\theta}{2} \qquad \left(\theta_1 = \frac{\theta}{2}\right)$

$= 5M_p\theta$

By the principle of virtual work:

Internal work done = External work done

$$\Rightarrow \quad 5M_p\theta = 140\theta$$

$$\Rightarrow \quad M_p = \frac{140}{5} = 28 \text{ kNm}$$

29. (a)

∵ Column is fixed at both ends.

So, $kL = 0.65 \times 4 = 2.6$ m

$r_{min} = 54$ mm

$$f_{cc} = \frac{\pi^2 E}{\left(\frac{kL}{r_{\min}}\right)^2} = \frac{\pi^2 \times 2 \times 10^5}{\left(\frac{2.6 \times 10^3}{54}\right)^2}$$

$= 851.47$ N/mm^2

So non-dimensional effective slenderness ratio

$$\lambda = \sqrt{\frac{f_y}{f_{ec}}} = \sqrt{\frac{250}{851.47}} = 0.542$$

30. (b)

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

$W = 60$ mm, $t = 6$ mm, $f_y = 250$ MPa, $f_u = 410$ MPa, $b_s = 60 + 50 - 6 = 104$ mm, $L_c = 3 \times 50 = 150$ mm

$\beta = 1.08$

■■■■