CLASS TEST

S.No.: 01DLSKCE_ABC_130726

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Design of Steel Structures

CIVIL ENGINEERING

Date of Test : 13/07/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. **(c)**

Shape factors of some cross-section are as follows:

(i) Rectangle - 1.5
(ii) I-section - 1.14
(iii) Diamond - 2
(iv) Triangle - 2.34
(v) Circle - 1.7

2. **(c)**

In case of plastic moment M_p, neutral axis passes through the point which divides the given section into two equal parts having equal area. Thus neutral axis must lie between yy and zz.

3. **(d)**

Maximum value of slenderness ratio as IS 800 : 2007.

S.No.	Type of Member	(λ)
1.	Tension member prone to reversal of stresses due to the loads other then wind or earthquake.	180
2.	Member carrying compressive loads due to dead and live loads.	180
3.	Member carrying compressive force due to the combination of wind and earthquake only provided deformation of such members does not adversely effect the stress in any part of the structure.	250
4.	Compression flange of a beam restrained against lateral torsional buckling.	300
5.	A member normally acting as a tie in a roof truss or a bracing system not considered when subjected to possible reversal of stresses due to wind or earthquake forces.	350

4. **(c)**

If the shear force to be transferred in the beam is large that seat angle may fail, to strengthen it, a stiffer angle may be provided. Such connections are known as stiffened seated connection.

5. **(b)**

When thin webs are used, it result in buckling due to shear. Hence intermediate transverse stiffeners are provided to improve buckling strength of web.

6. **(d)**

Refer IS 800 : 2007, Clause 10.3.3.2

7. **(c)**

8. **(c)**

Number of possible location of plastic hinges

$$= 6\{A, B, C, D, E, F\}$$

Degree of static indeterminacy = 6 – 3 = 3

$\therefore$ Number of possible independent mechanisms = 6 – 3 = 3
Two beam mechanisms and one sway mechanism.

9. **(a)**

$$\text{Axial load} = 600 \text{ kN}$$

Maximum shear,
$$V = \frac{2.5}{100} \times 600 \times 10^3 = 15000 \text{ N}$$

$$\text{Transverse shear in each panel} = \frac{V}{N} = \frac{15000}{2} = 7500 \text{ N}$$

$$\text{Compressive force in lacing bars} = \frac{V}{N} \operatorname{cosec}\theta$$
$$= 7500 \operatorname{cosec} 45° = 10606.6 \text{ N}$$
$$= 10.607 \text{ kN} \approx 10.61 \text{ kN}$$

10. **(a)**

11. **(c)**

For efficient minimum spacing 'S' between the channels,

$$I_{yy} \geq I_{xx}$$

Now
$$I_{xx} = 2 \times 10000 \times 10^4 = 20000 \times 10^4 \text{ mm}^4$$

$$I_{yy} = 2\left[434 \times 10^4 + \left(24.4 + \frac{S}{2}\right)^2 \times 5366\right]$$

Now,
$$I_{yy} \geq I_{xx}$$

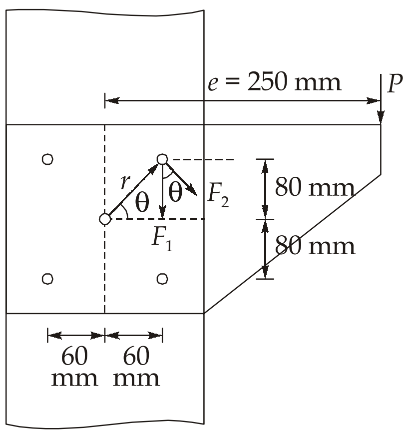
$$\Rightarrow \quad 2\left[434 \times 10^4 + \left(24.4 + \frac{S}{2}\right)^2 \times 5366\right] \geq 20000 \times 10^4$$

$$S \geq 218.20 \text{ mm}$$

12. **(c)**

Bolt value of each bolt = 45.27 kN

Now force in extreme bolt is computed as below.



Direct shear force,
$$F_1 = \frac{P}{n} = \frac{P}{5} = 0.2P$$

Now, centre of gravity of bolted connection is at the centre of central bolt

For four extreme bolts, $r = \sqrt{80^2 + 60^2} = 100$ mm

For central bolt, $r = 0$

$\therefore \quad \Sigma r^2 = 4 \times (100)^2 = 4 \times 10^4 \text{ mm}^2$

For extreme bolt, $r = 100$ mm

$\therefore$ Force due to bending moment in extreme bolt

$$F_2 = \frac{P \times e \times r}{\Sigma r^2} = \frac{P \times 250 \times 100}{4 \times 10^4} = 0.625\,P$$

Angle between the two forces F_1 and F_2 is θ which is calculated as:

$$\cos\theta = \frac{60}{r} = \frac{60}{100} = 0.6$$

$\therefore$ Total force on extreme bolt

$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta} = \sqrt{(0.2P)^2 + (0.625\,P)^2 + 2 \times 0.2P + 0.625P \times 0.6}$$

$$= 0.76199\,P$$

Equating it to the bolt value of bolt,

We get, $0.76199\,P = 45.27$

$\Rightarrow \quad P = 59.41$ kN

13. (b)

$\because$ Section is plastic (given)

And $V < 0.6\,V_d$

So, it is a case of low shear and thus design bending

$$M_d = \frac{\beta_b Z_p f_y}{\gamma_{m0}} \le \frac{1.2 Z_e f_y}{\gamma_{m0}}$$

$\beta_b = 1$ for plastic section

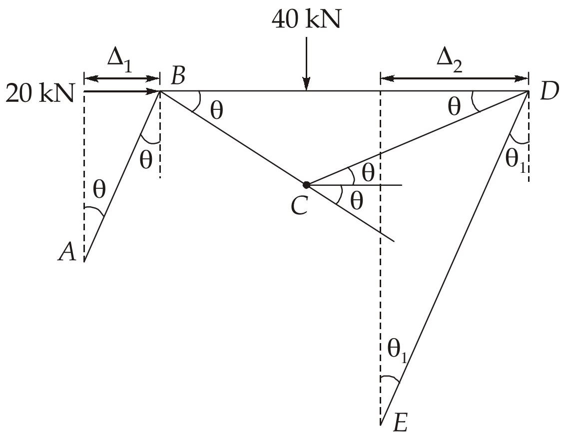
So, $$M_d = \frac{1 \times 651.74 \times 10^3 \times 250}{1.1 \times 10^6} \le \frac{1.2 \times 573.6 \times 10^3 \times 250}{1.1 \times 10^6}$$

$= 148.12 \text{ kNm} \le 156.44 \text{ kNm}$ (OK)

So design bending strength = 148.12 kNm.

14. (c)

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



$$\Delta_1 = \Delta_2$$

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

$$\Rightarrow \qquad \theta = 2\theta_1$$

$$\text{External work done} = \Sigma \text{ load} \times \text{Deflection}$$

$$= 40 \times 2\theta + 20 + 3\theta = 140\theta$$

$$\text{Internal work done} = \Sigma \text{ plastic moment} \times \text{Rotation}$$

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

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

$$= 5M_p\theta$$

By the principle of virtual work:

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

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

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

15. (b)

For Fe410 steel,

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

$$f_y = 250 \text{ N/mm}^2$$

Tensile strength due to rupture of critical section.

Length of outstanding leg, w = 115 mm

Weld length along the direction of load,

$$L_c = \frac{150+60}{2} = 105 \text{ mm}$$

Width of shear lag, b_s = 115 mm

$$\beta = 1.4 - 0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right) \le \frac{0.9 f_u \gamma_{m0}}{f_y \gamma_{m1}} \ge 0.7$$

$$= 1.4 - 0.076\left(\frac{115}{8}\right)\left(\frac{250}{410}\right)\left(\frac{115}{105}\right) = 0.67$$

$$\frac{0.9 f_u \gamma_{m0}}{f_y\ \gamma_{m1}} = \frac{0.9 \times 410 \times 1.1}{250 \times 1.25} = 1.29888 > 0.7$$

$$0.7 < \beta < 1.29888$$

$$\therefore \qquad \beta = 0.7$$

Area of connected leg, $A_{nc} = \left(150 - \frac{8}{2}\right)8 = 1168 \text{ mm}^2$

Area of outstanding leg, $A_{go} = \left(115 - \frac{8}{2}\right)8 = 888 \text{ mm}^2$

$$\therefore \qquad T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{m1}} + \beta \frac{A_{go} f_y}{\gamma_{m0}}$$

$$= \left(\frac{0.9(1168)410}{1.25} + \frac{0.7(888)250}{1.1}\right)\text{N} = (344.79+141.272) \text{ kN} = 486.06 \text{ kN}$$

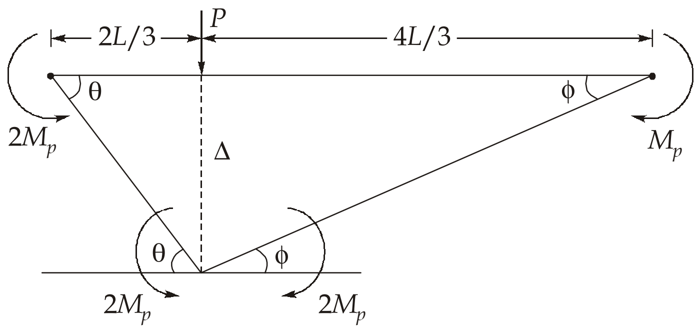
16. (d)

$$D_s = 2$$

∴ Number of plastic hinge required for complete collapse

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

Mechanism-1:



$$\Delta = \frac{2L}{3}\theta = \frac{4L}{3}\phi$$

$$\theta = 2\phi$$

For principal of virtual work,

$$-2M_p\theta - 2M_p\theta - 2M_p\phi - M_p\phi + P\left(\frac{2L}{3}\theta\right) = 0$$

$$\Rightarrow \quad 4M_p\theta + 3M_p\phi = \frac{2PL}{3}\theta$$

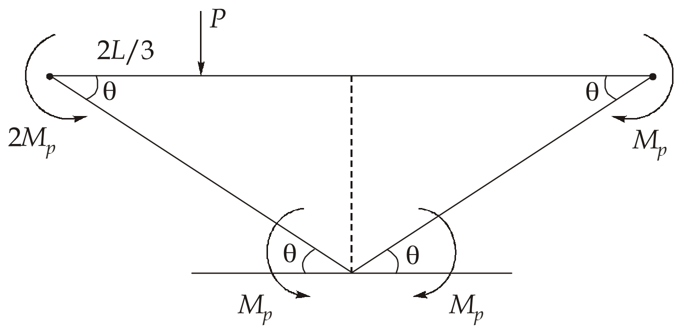
$$\Rightarrow \quad 8M_p\phi + 3M_p\phi = \frac{4PL}{3}\phi$$

$$\Rightarrow \quad 11M = \frac{4PL}{3}$$

$$\Rightarrow \quad P = \frac{33}{4}\frac{M_p}{L} \quad \left(\because \text{Collapse load} = 7.5\frac{M_p}{L}\right)$$

$$\Rightarrow \quad P = \frac{8.25M_p}{L}$$

Mechanism-2:



$$2M_p\theta + M_p\theta + M_p\theta + M_p\theta = P\left(\frac{2L}{3}\right)\theta$$

$$\Rightarrow \quad 5M_p = \frac{2PL}{3}$$

$$\Rightarrow \quad P = \frac{15M_p}{2L}$$

$$\Rightarrow \quad P = \frac{7.5M_p}{L}$$

$$\therefore \quad \text{Collapse load} = \text{min.}\left[7.5\frac{M_p}{L}, 8.25\frac{M_p}{L}\right]$$

17. (c)

Plastic section modulus, $Z_p = 2\left(A_1\bar{y}_1 + A_2\bar{y}_2\right)$

$= 2\ [20 \times 200 \times 10 + 40 \times 80 \times 60]$

$= 46.4 \times 10^4\ \text{mm}^3$

Moment of inertia, $$I = \frac{200 \times (40)^3}{12} + 2\left[\frac{40 \times 80^3}{12} + 40 \times 80 \times 60^2\right]$$

$= 2752 \times 10^4\ \text{mm}^4$

So elastic section modulus, $Z_e = \dfrac{I}{y} = \dfrac{2752 \times 10^4}{100} = 27.52 \times 10^4\ \text{mm}^3$

So shape factor, $S = \dfrac{Z_P}{Z_e} = \dfrac{46.4 \times 10^4}{27.52 \times 10^4} = 1.686$

18. (a)

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

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

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

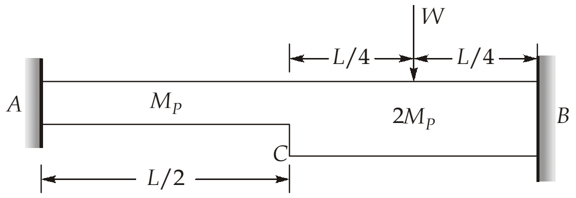
$$\Rightarrow \quad \frac{410}{\sqrt{3} \times 1.5} \times L_w \times 5.6 = 300 \times 10^3$$

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

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

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

19. (c)



Degree of static indeterminacy, $D_s = 2$

$\therefore$ No. of plastic hinges required for collapse,

$$n = D_s + 1 = 3$$

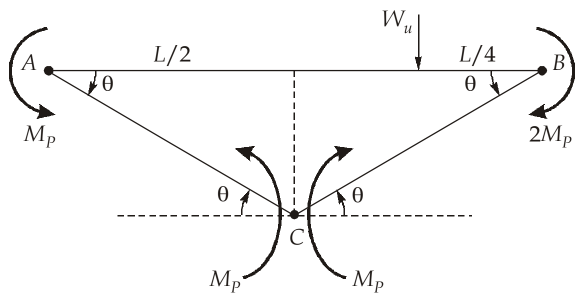
Possible location of plastic hinges are at A, B, C and under the load,

$$\therefore \quad N = 4$$

Number of independent mechanisms $= N - D_s = 4 - 2 = 2$

Mechanism: 1

Formation of plastic hinges at A, B and C



By the principle of virtual work

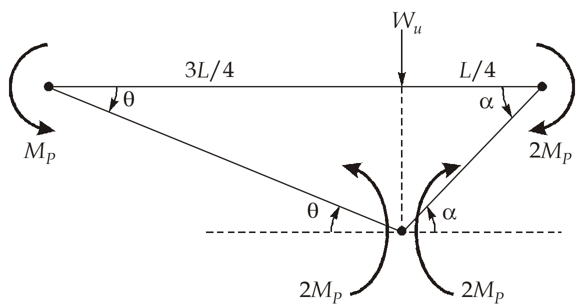
$$W_i = W_E$$

$$\Rightarrow \quad 5M_p\theta = W_u \times \frac{L}{4}\theta$$

$$\Rightarrow \quad W_u = \frac{20M_P}{L}$$

Mechanism: 2

Formation of plastic hinges at A, B and under the point load.



$$\frac{3L}{4}\theta = \frac{L}{4}\alpha$$

$$\Rightarrow \quad \alpha = 3\theta$$

By the principle of virtual work

$$W_i = W_E$$

$$\Rightarrow \qquad 3M_p\theta + 4M_p\alpha = W_u \times \frac{L}{4}\alpha$$

$$\Rightarrow \qquad 3M_p\theta + 4M_p(3\theta) = W_u \times \frac{L}{4} \times 3\theta$$

$$\Rightarrow \qquad W_u = \frac{20M_P}{L}$$

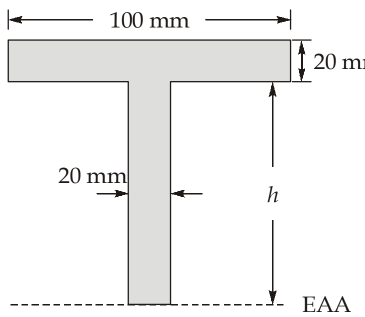
Hence, Collapse load = Minimum of above two loads = $\frac{20M_P}{L}$

20. (a)

Plastic section modulus, $Z_p = \frac{A}{2} \times [\bar{y}_1 + \bar{y}_2]$

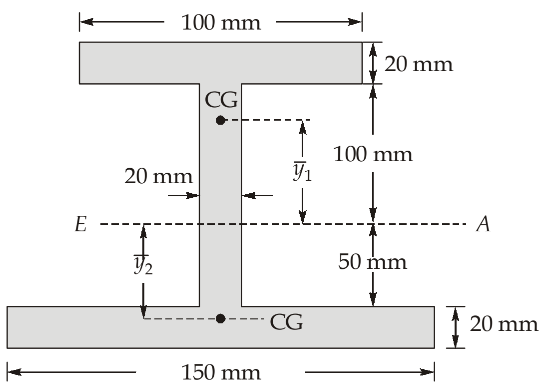
$$A = (100 \times 20) + (150 \times 20) + (150 \times 20) = 8000 \text{ mm}^2$$

Calculation of equal area axis:



$$\therefore \qquad \frac{A}{2} = 4000 = (100 \times 20) + 20 \times h$$

$$\Rightarrow \qquad h = 100 \text{ mm}$$



$$\bar{y}_1 = \frac{100 \times 20 \times 110 + 100 \times 20 \times 50}{4000} = 80 \text{ mm}$$

$$\bar{y}_2 = \frac{50 \times 20 \times 25 + 150 \times 20 \times 60}{4000} = 51.25 \text{ mm}$$

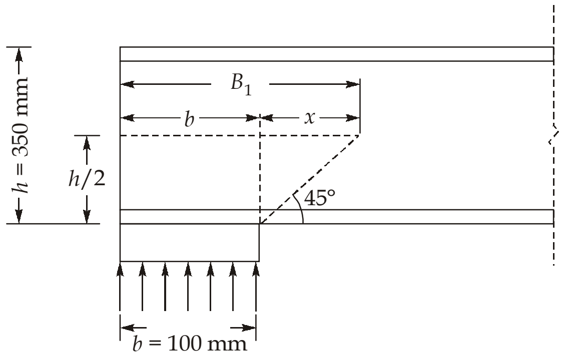
$$\therefore \quad Z_p = \frac{8000}{2}[80 + 51.25] = 525000 \text{ mm}^3 = 525 \text{ cm}^3$$

21. (c)

Depth of web: $d = h - 2\,(t_f + R_1)$
$= 350 - 2\,(11.2 + 16)$
$= 295.2$ mm

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

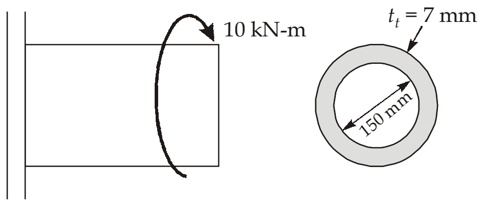
From table given: $f_{cd} = 121 + \frac{107 - 121}{100 - 90}(99.73 - 90) = 107.38 \text{ N/mm}^2$



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

$\therefore$ Web buckling strength, $F_{wb} = B_1 \times t_w \times f_{cd}$
$= 275 \times 7.4 \times 107.38 \times 10^{-3}$ kN
$= 218.52$ kN

22. (b)



Throat thickness, $t = 0.7 \cdot s$ where s is size of weld.
$= 0.7 \times 10 = 7$ mm

Now, maximum shear stress in weld, $f_s = \frac{T}{Z_p}$

here Z_p = Polar modulus of weld area
$= A \times r$

$$= \pi d \cdot t \cdot \times \frac{d}{2}$$

$$= \pi d^2 \times \frac{t}{2}$$

So, $$f_s = \frac{10 \times 10^6}{\pi \times 150^2 \times \frac{7}{2}} = 40.4 \text{ N/mm}^2$$

23. (a)

Given: wind speed, $V_b = 47$ m/s

$k_1 = 1$

$k_2 = 0.96$

$k_3 = 1$

$k_4 = 1$

$\therefore$ Design wind speed, $V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4$

$V_z = 47 \times 1 \times 0.96 \times (1 \times 1)$

$= 45.12$ m/s

Basic wind pressure, $p_z = 0.6 \times V_z^2$

$= 0.6 \times 45.12^2$

$= 1221.49$ N/m^2

$= 1.22$ kN/m^2

24. (d)

The Principal moment of inertia,

$$I_{uu}, I_{vv} = \frac{I_{xx} + I_{yy}}{2} \pm \sqrt{\left(\frac{I_{xx} - I_{yy}}{2}\right)^2 + I_{xy}^2}$$

$$= \frac{2 \times 10^7 + 0.97 \times 10^7}{2} \pm \sqrt{\left(\frac{2 \times 10^7 - 0.97 \times 10^7}{2}\right)^2 + (0.83 \times 10^7)^2}$$

$$= 1.48 \times 10^7 \pm \sqrt{0.26 \times 10^{14} + 0.69 \times 10^{14}}$$

$$= 1.485 \times 10^7 \pm 0.97 \times 10^7$$

$\therefore$ $I_{uu} = (1.48 + 0.97) \times 10^7 = 2.45 \times 10^7$ mm^4

$I_{vv} = (1.48 - 0.97) \times 10^7 = 0.51 \times 10^7$ mm^4

$\therefore$ Least moment of inertia, $I_{min} = I_{vv} = 0.51 \times 10^7$ mm^4

$\therefore$ Minimum radius of gyration, $r_{min} = \sqrt{\frac{I_{min}}{A}}$

$$= \sqrt{\frac{0.51 \times 10^7}{5025}} = 31.86 \text{ mm}$$

$\therefore$ Slenderness ratio, $\lambda = \frac{l_{eff}}{r_{min}}$

$$= \frac{4.5 \times 10^3}{31.86} = 141.24$$

Now, permissible compressive stresses (σ_{ac}),

$$\sigma_{ac} = 51 - \left[\frac{51 - 45}{150 - 140}\right] \times (141.24 - 140)$$

$$= 50.256 \text{ MPa}$$

$$\text{Safe load, } F = \sigma_{ac} \times A = 50.256 \times 5025 \times 10^{-3} \text{ kN} = 251.72 \text{ kN}$$

25. (b)

$$\text{Applied shear force} = 220 \text{ kN}$$
$$\text{Factored shear force, } V = 1.5 \times 220 = 330 \text{ kN}$$
$$\text{Design shear capacity, } V_d = 410 \text{ kN}$$
$$0.6\,V_d = 0.6 \times 410 = 246 \text{ kN} < 330 \text{ kN}$$

So, it is a case of high shear.

Now,
$$\beta = \left(\frac{2V}{V_d} - 1\right)^2$$

$\therefore$
$$= \left(\frac{2 \times 330}{410} - 1\right)^2 = 0.37$$

26. (a)

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

$$w = 60 \text{ mm}$$
$$t = 6 \text{ mm}$$
$$f_y = 250 \text{ MPa}$$
$$f_u = 410 \text{ MPa}$$
$$b_s = 60 + 50 - 6 = 104 \text{ mm}$$
$$L_c = 2 \times 50 = 100 \text{ mm}$$

So,
$$\beta = 1.4 - 0.076\left(\frac{60}{6}\right)\left(\frac{250}{410}\right)\left(\frac{104}{100}\right) = 0.91$$

27. (c)

It is a deflection caused by bending about the axis corresponding to the largest slenderness ratio.

28. (a)

For minimum required overlap length,

$$P_u = \frac{k_s l_{eff} \times f_w}{\sqrt{3}(\gamma_{mw})_{\text{field}}}$$

$$\Rightarrow \quad 400 \times 10^3 = \frac{0.7 \times 6 \times 4x \times 410}{\sqrt{3} \times 1.50}$$

$$\Rightarrow \quad x = 150.88 \text{ mm} \simeq 151 \text{ mm}$$

29. (b)

Direct vertical shear force, $F_1 = \dfrac{P}{n}$

$$\Rightarrow \quad F_1 = \frac{P}{4} + \frac{P}{4} = \frac{P}{2}$$

Shear force due to torsional moment (F_2)

$$F_2 = \frac{P.e.r}{\Sigma r^2}$$

Here, $e = 300$ mm, $r = \sqrt{90^2 + 120^2} = 150\,\text{mm}$

$$\therefore \quad F_2 = \frac{P \times 300 \times 150}{4 \times 150^2} - \frac{P \times 300 \times 150}{4 \times 150^2} = 0$$

$$\therefore \text{ Resultant force,} \quad F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$\Rightarrow \quad F_R = F_1 = \frac{P}{2}$$

30. (c)

Optimum depth of plate girder, d = $\left(\dfrac{Mk}{f_y}\right)^{1/3}$

$$\Rightarrow \quad d = \left(\frac{9500 \times 10^6 \times 180}{250}\right)^{1/3}$$

$$\Rightarrow \quad d = 1898.2 \text{ mm} \simeq 1900 \text{ mm}$$

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