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DESIGN OF STEEL STRUCTURES

CIVIL ENGINEERING

Date of Test : 18/07/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

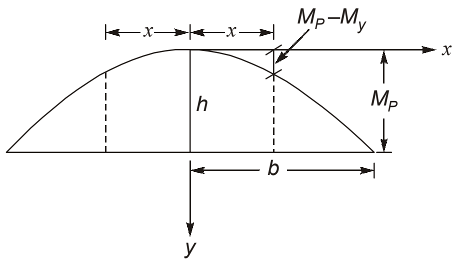
2. (b)
If the compression flange is restrained laterally against buckling or if the beam is not to bend about the axis of minimum strength (y - y) axis, the beam is said to be laterally restrained.

4. (a)

$$\text{Plastic hinge length, } L_P = l\sqrt{1-\frac{1}{SF}}$$

Proof:

From similar parabolas concept,



$$y = kx^2 \; ; \qquad \frac{x^2}{y} = \text{constant}$$

$$\frac{x^2}{(M_P - M_y)} = \frac{(l/2)^2}{M_P}$$

$$x^2 = \left(\frac{l}{2}\right)^2 \times \left(\frac{M_P - M_y}{M_P}\right)$$

$$x = \frac{l}{2} \times \sqrt{1-\frac{1}{SF}}$$

$$\Rightarrow \quad L_P = 2x = l \times \sqrt{1-\frac{1}{SF}}$$

where, SF = Shape factor
= 2 for diamond cross-section

$$= l\sqrt{1-\frac{1}{2}}$$

$$L_P = \frac{l}{\sqrt{2}} = kl$$

$$\Rightarrow \quad k = 0.707$$

5. (c)
Since in purlins, maximum moment about both the principal axes are not equal i.e., one moment is lesser than the other. So, there is no point in giving equal section modulus in both the principal axes. Hence, equal angles are not economical in case of purlins.

7. (b)

$$f_u = 600 \text{ MPa}$$
$$f_y = 0.8 \times 600 = 480 \text{ MPa}$$

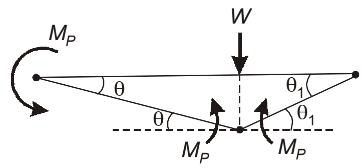
8. (a)

$$\text{Radius of gyration of steel bar, } r = \frac{D}{4} = \frac{20}{4} = 5 \text{ mm}$$

$$\lambda_{max} = 180$$

$$\therefore \quad l_{max} = \lambda_{max} \times r$$
$$= 180 \times 5 = 900 \text{ mm}$$

11. (c)



$$\text{Number of plastic hinges} = D_s + 1 = 2$$

From principle of virtual work,

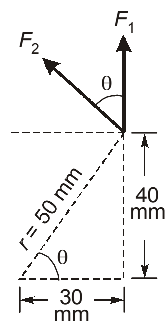
$$M_P(\theta) + M_P(\theta + \theta_1) = W \times a$$

$$\therefore \quad 4M_P\theta = W \times 2 \qquad \{\because \theta_1 = 2\theta\}$$

$$\therefore \quad W = 2M_P$$

12. (c)

Since, the bolt value is the minimum of shear strength and bearing strength. So, in this case, bolt value is 45 kN. Since, the maximum stress will be in top and rightmost bolt.



$$\therefore \quad \text{Direct shear force } (F_1) = \frac{P}{5} = 0.2P$$

$$\text{Shear force due to moment } (F_2) = \frac{Pe \cdot r}{\Sigma r^2}$$

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

$$\therefore \quad F_2 = \frac{P \times 100 \times 50}{4 \times 50^2} = 0.5P$$

$$\therefore \quad \text{Resultant shear force } (F_R) = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta} \qquad \left[\cos\theta = \frac{30}{\sqrt{40^2 + 30^2}} = \frac{3}{5}\right]$$

$$F_R = \sqrt{(0.2P)^2 + (0.5P)^2 + 2(0.2P)(0.5P) \times \frac{3}{5}}$$

$$= 0.64P \le 45$$

$$\Rightarrow \quad P \le 70.28 \text{ kN}$$

12. (a)

$$\text{For lacing plate, } I = \frac{bt^3}{12}$$

$$\because \quad r = \sqrt{\frac{I}{A}} = \sqrt{\frac{bt^3}{12 \times bt}} = \frac{t}{\sqrt{12}}$$

$$\text{Also,} \quad \lambda = \frac{KL}{r} < 145$$

$$\therefore \quad \frac{L}{\frac{t}{\sqrt{12}}} < 145$$

$$\Rightarrow \quad L < \frac{145 \times 5\sqrt{12}}{\sqrt{12}} = 725\text{mm}$$

Therefore, maximum value of L is 725 mm.

14. (c)

Design strength of weld, $P_{dw} = l_w \times t_t \times \dfrac{f_u}{\sqrt{3}\,\gamma_{mw}}$ ...(i)

Minimum permissible weld size upto 20 mm thick plate as per **IS 800:2007** is

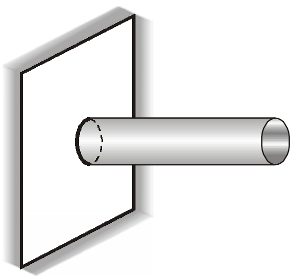
$$s = 5 \text{ mm}$$
$$t_t = 0.7 \times 5 = 3.5 \text{ mm} \qquad (> 3 \text{ mm})$$

Substituting in equation (i)

$$\Rightarrow \quad 200 \times 10^3 = l_w \times 3.5 \times \frac{410}{\sqrt{3} \times 1.5}$$

$$\Rightarrow \quad l_w = 362.1 \text{ mm}$$

15. (d)



$$\frac{f}{r} = \frac{T}{J}$$

$$f = \frac{T \cdot d/2}{\frac{\pi}{4} \cdot d^3 \cdot t} = \frac{2T}{\pi d^2 t} \qquad \left[\because \; J = \frac{\pi}{4} d^3 t\right]$$

Alternatively,

$$T = F \cdot r$$
$$F = \text{Shear force} = \text{Stress} \times \text{Area}$$
$$= f \times (\pi d \times t)$$
$$r = \frac{d}{2}$$
$$T = f \times \pi dt \times \frac{d}{2}$$
$$f = \frac{2T}{\pi d^2 t}$$

16. (c)

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

where V_b = Basic wind speed = 47 m/s

So, $V_z = 1 \times 0.92 \times 1 \times 1.15 \times 47 = 49.726$ m/s

Wind pressure at height 'z' is

$$P_z = 0.6\, V_z^2$$
$$= 0.6 \times (49.726)^2 = 1483.6 \text{ N/m}^2 \text{or } 1.48 \text{ kN/m}^2$$

17. (c)

Tearing efficiency of a joint can be given by = $\dfrac{p - d_h}{p}$

d_h = diameter of rivet hole, p = pitch

$$\eta = 1 - \frac{d_h}{p} \text{ and } \frac{d_h}{p} = 0.25 \text{ (given)}$$

$\therefore$ $\eta = 1 - 0.25 = 0.75$

or $\eta = 75\%$

18. (b)

Let, P_1 be the factored load,

So, service load, $P = \dfrac{P_1}{1.5}$

The bolt which is stressed maximum is bolt A,

Direct force, $F_1 = \dfrac{P_1}{n} = \dfrac{P_1}{10}$

Force in the bolt due A to torque,

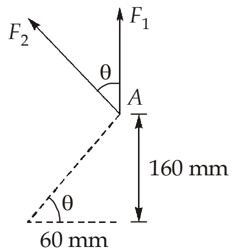
$$F_2 = \frac{Per_A}{\Sigma r_i^2}$$

Now, $r_A = \sqrt{160^2 + 60^2} = 170.88$ mm

$\Sigma r_i^2 = 4[160^2 + 60^2] + 4[80^2 + 60^2] + 2 \times 60^2 = 164000$ mm^2

$\therefore$ $F_2 = \dfrac{P_1 \times 250 \times 170.88}{164000} = 0.2605P_1$

Also, $\cos\theta = \dfrac{60}{\sqrt{160^2 + 60^2}} = 0.3511$



The resultant force on the bolt A should be less than or equal to the strength of bolt

$$45.26 \geq \sqrt{\left(\frac{P_1}{10}\right)^2 + (0.2605P_1)^2 + 2 \times \frac{P_1}{10} \times 0.2605P_1 \times 0.3511}$$

On solving we get, $P_1 = 145.96$ kN

$\therefore$ Maximum service load, $P = \dfrac{145.96}{1.5} = 97.307 \text{ kN} \approx 97.31$ kN

19. (b)

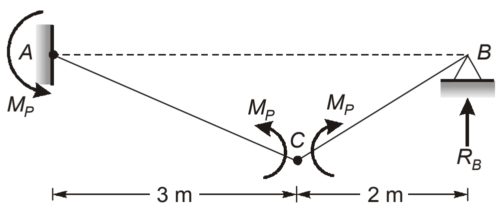
$\because$ Load factor = Factor of safety $\times$ Shape factor

When permissible stress is increased by 15%, FOS will reduce by

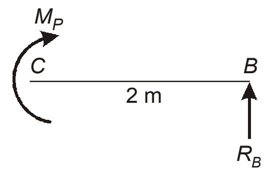
$$\frac{\text{FOS}}{1.15} = \frac{1.5}{1.15}$$

$$\text{Load factor} = \left(\frac{1.5}{1.15}\right) \times 1.5 = 1.96$$

20. (d)

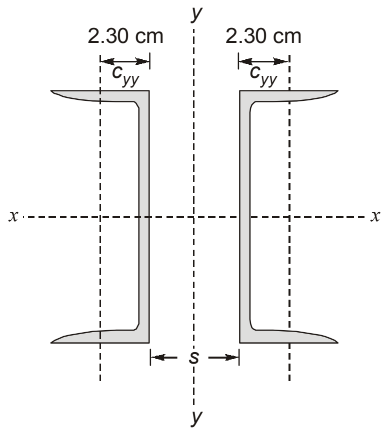


Portion BC



$$\Rightarrow \quad M_P = 2 \times R_B$$
$$\Rightarrow \quad 60 = 2 \times R_B$$
$$\Rightarrow \quad R_B = 30 \text{ kN}$$

21. (c)



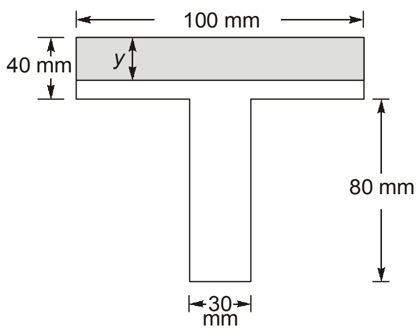
For optimum strength,

$$I_{xx} = I_{yy} \text{ (of section)}$$

$$\Rightarrow \quad 3816.8 \times 2 = \left[219.1 + 38.67\left(2.30 + \frac{s}{2}\right)^2\right] \times 2$$

$$\Rightarrow \quad s \simeq 14.7 \text{ cm}$$

22. (a)



We know that in plastic condition neutral axis will be equal area axis

So,

Calculation of location of equal area axis

Total area of section, $A = 40 \times 100 + 80 \times 30$
$= 6400 \text{ mm}^2$

$$\therefore \quad \frac{A}{2} = 3200 \text{ mm}^2$$

Taking distance from top,

$$100 \times y = 3200$$

$\Rightarrow \qquad y = 32$ mm

This means, top 32 mm flange is in compression

$\therefore$ Compressive force = Area × Stress

$= (32 \times 100) \times 250$

$= 800$ kN

23. (d)

Axial tension = 200 kN

Since, it is carried by two angles

So, tension carried by one angle = 100 kN

$$\text{Strength of weld} = \left(\frac{410 \times 0.7 \times 6}{\sqrt{3} \times 1.25}\right) = 795.36 \text{ N/mm}$$

$$\therefore \text{ Length of weld required} = \frac{100 \times 1000}{795.36} = 125.73 \simeq 126 \text{ mm}$$

24. (b)

As per IS specification, $k = 0.7$ (for fusion angle ranging from 60° to 90°)

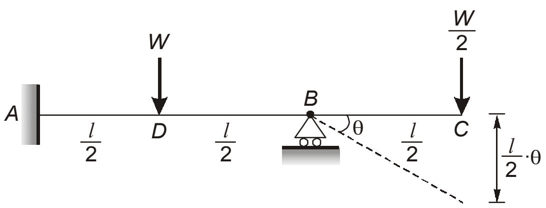
So throat thickness $= 0.7 \times 8 = 5.6$ mm

25. (a)

Section	SF
I-section	1.12
Hollow Tube Section	1.27
Diamond Section	2
Triangular Section	2.34
Circular Section	1.7

26. (c)

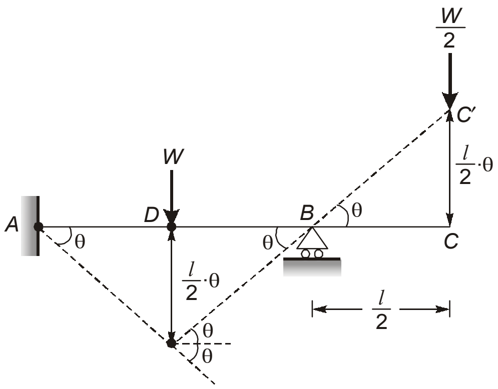
Case I: plastic hinge at *B* alone



$$(W \times 0) + \frac{W}{2}\left(\frac{l}{2}\cdot\theta\right) = M_P(\theta)$$

$$W = \frac{4M_P}{l}$$

Case II: plastic hinge at A and D



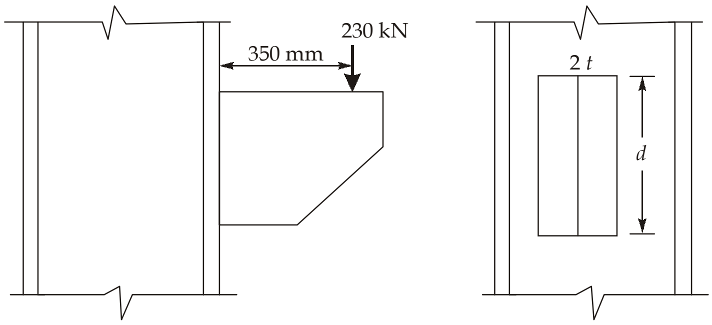
$$W\left(\frac{l}{2}\cdot\theta\right)-\frac{W}{2}\left(\frac{l}{2}\cdot\theta\right) = M_P(\theta)+M_P(\theta+\theta)$$

$$\Rightarrow \qquad \frac{Wl\theta}{4} = 3M_P\theta$$

$$\Rightarrow \qquad W = \frac{12M_P}{l}$$

$$\therefore \qquad \text{Collapse load, } W = W_u = \frac{4M_P}{l}$$

27. (a)



Direct shear stress, $q = \dfrac{P}{2t\times d}$ where t is throat thickness = 0.7 × size of weld

$$= \frac{230\times10^3}{2\times0.7\times10\times400} = 41.07 \text{ N/mm}^2$$

Bending stress, $f_b = \dfrac{M}{I}\times y$

$$= \frac{P.e}{\dfrac{2t\cdot d^3}{12}}\times\frac{d}{2}$$

$$= \frac{230\times10^3\times350\times12\times400}{2\times0.7\times10\times400^3\times2}$$

$$= 215.63 \text{ N/mm}^2$$

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

$$= \sqrt{(215.63)^2+3\times(41.07)^2} = 227.06 \text{ N/mm}^2$$

30. (b)

Effective length column = $kl = 1 \times 6 = 6$ m [$k = 1$ since column is hinged at both the ends]

$$\therefore \quad \text{Slenderness ratio} = \frac{kl}{r_{min}} = \frac{6 \times 1000}{53.4} = 112.36$$

$\therefore$ Design compressive strength,

$$f_{cd} = 72 - \frac{(112.36 - 110)}{(120 - 110)} \times (72 - 64)$$

$$= 70.112 \text{ N/mm}^2$$

$$F = 70.112 \times 8591 \times 10^{-3} = 602.3 \text{ kN}$$

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