CLASS TEST

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Design of Steel Structures

CIVIL ENGINEERING

Date of Test : 06/09/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

At the lower yield point, the specimen starts stretching at practically constant stress.

2. (c)

$$\text{Efficiency of joint} = \frac{\text{Strength of bolt}}{\text{Strength of joint}} \times 100$$

$$= \frac{\min(225, 300)}{250} \times 100$$

$$\eta = \frac{225}{250} \times 100 = \frac{9}{10} \times 100 = 90\%$$

3. (b)

For a bolt of diameter 18 mm

$$e_{\min} = 1.5\, d_o$$

$$d_o = 18 + 2 \qquad \text{(For } d > 16 \text{ mm)}$$

$$= 20 \text{ mm}$$

$$e_{\min} = 1.5 \times 20 = 30 \text{ mm}$$

4. (d)

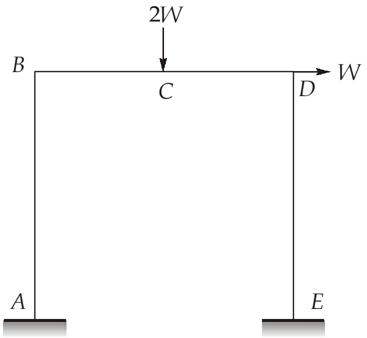
5. (b)

For a welded girder, $$\frac{b}{t_f} = 6.7 < 8.4\,\epsilon \qquad \text{(Flanges are plastic)}$$

And $$\frac{d}{t_w} = 91 < 105\,\epsilon \qquad \text{(Web is compact)}$$

Overall section is compact.

6. (a)



The possible locations of the hinges are at A, B, C, D and E

Number of possible plastic hinges,

$$N = 5$$

Degree of redundancy, $$r = 6 - 3 = 3$$

Number of possible independent mechanisms,

$$n = N - r$$
$$n = 5 - 3 = 2$$
$$\text{Ratio} = \frac{5}{2} = 2.5$$

7. (c)

IS 800 : 2007 (When $l_j > 15d$)

then
$$\beta_{l_j} = 1.075 - \frac{l_j}{200d}$$
$$l_j = 300 \text{ mm}, \quad d = 16 \text{ mm}$$
$$\beta_{l_j} = 1.075 - \frac{300}{200 \times 16} = 0.98125$$

8. (d)

9. (a)

The webs of rolled steel sections are subjected to a large amount of stresses just below the concentrated loads and above the reactions from the support. Stress concentration occurs at the junction of the web and the flange. As a result, large bearing stresses are developed below the concentrated loads. The web near the portion of the stress concentration tends to fold over the flange. This type of local buckling phenomenon is called crippling or crimpling of the web.

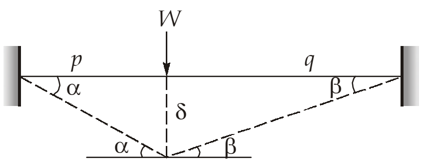
The web of the plate girder being relatively tall and thin is a poor compression member and hence, the possibility of vertical and diagonal buckling is always there. Either the web is stiffened vertically as well as horizontally or the compressive stress in the web is kept low enough by increasing the web thickness to prevent crippling.

10. (b)

$$\text{Throat thickness} = 0.7 \times \text{size of weld}$$
$$= 0.7 \times 10 = 7 \text{ mm}$$
$$\text{Safe force} = (70 + 50 + 70) \times 7 \times 120 = 160 \text{ kN}$$

11. (b)

12. (c)



$$\left\{\begin{aligned} P\alpha &= q\beta \\ \alpha &= \frac{q\beta}{P} \end{aligned}\right.$$

Kinematic method
$$W \times \delta = 2M_p\alpha + 2M_p\beta$$
$$W \times \delta = 2M_p\frac{q\beta}{P} + 2M_p\beta$$

$$W \times (\beta q) = 2M_p \frac{q\beta}{P} + 2M_p\beta$$

$$Wq = 2M_p \frac{q}{P} + 2M_p$$

$$Wq = \frac{2M_p[q+P]}{P}$$

$$W_c = \frac{2M_p[q+P]}{Pq}$$

13. (b)

$$A_{vn} = (50 + 100 - 1.5 \times 18) \times 8 = 984 \text{ mm}^2$$

$$A_{tn} = (35 - 0.5 \times 18) \times 8 = 208 \text{ mm}^2$$

$$\text{Ratio} = \frac{A_{vn}}{A_{tn}} = \frac{984}{208} = 4.73$$

14. (c)

15. (c)

Refer IS 800 : 2007, Clause 7.6

16. (b)

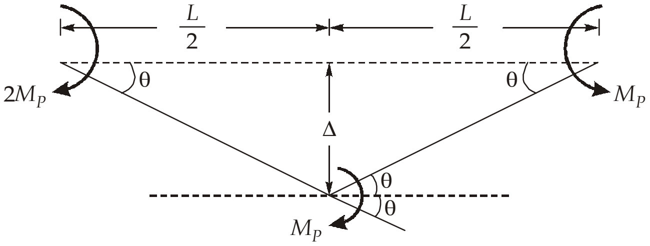
No. of independent mechanisms = Possible number of plastic hinges – Degree of redundancy

= 4 – 2 = 2

∵ Degree of redundancy = 2

∴ Number of plastic hinges required for collapse = 2 + 1 = 3

Case - I : Two plastic hinge at supports, and one plastic hinge at the point where cross – section changes. The plastic hinge will form at B in the limb BC and its value will be M_P.



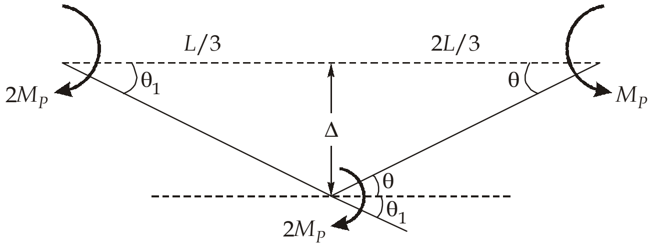
External work done = Internal work done

$$\Rightarrow \quad W \times \frac{L}{3}\theta = 2\,M_p\theta + M_p\,(\theta + \theta) + M_p\theta$$

$$\Rightarrow \quad W \times \frac{L}{3}\theta = 5\,M_p\theta$$

$$\Rightarrow \quad W = 15\frac{M_P}{L}$$

Case - II : Two plastic hinges at the supports and one below the concentrated load.



$$\Delta = \frac{L}{3}\theta_1 = \frac{2}{3}L\theta \Rightarrow \theta_1 = 2\theta$$

External work done = Internal work done

$$\Rightarrow \quad W \times \frac{L}{3}\theta_1 = 2M_p\theta_1 + 2M_p(\theta+\theta_1) + M_p\theta$$

$$\Rightarrow \quad \frac{2}{3}WL\theta = 2M_p \times (2\theta) + 2\,M_p\,(\theta + 2\theta) + M_p\theta$$

$$\Rightarrow \quad \frac{2}{3}WL\theta = 11\,M_p\theta$$

$$\Rightarrow \quad W = 16.5\frac{M_P}{L}$$

$$\text{So, collapse load} = 15\frac{M_P}{L}$$

17. (c)

18. (a)

When all the four angles are riveted together as shown they act as one unit.

$$I_y = I_x = 4\,[I_{xx} + a\,(C_{xx})^2]$$
$$= 4\,[735.4 \times 10^4 + 3459 \times (41.4)^2]$$
$$= 5313 \times 10^4 \text{ mm}^4$$

$$\text{Radius of Gyration, } r_{\min} = \sqrt{\frac{I_{\min.}}{A}} = \sqrt{\frac{5313\times10^4}{4\times3459}} = 61.97 \text{ mm}$$

$$\therefore \quad \text{Slenderness ratio, } \lambda = \frac{l_{eff}}{r_{\min}} = \frac{4500}{61.97} = 72.62$$

19. (b)

Weaker axis implies y-y axis.

$$\therefore \quad Z_{Py} = \frac{A}{2}\left(\bar{x}_1 + \bar{x}_2\right)$$

$$= \left[\frac{150\times10}{2}(37.5+37.5)\right]\times 2 + \left[\frac{(200-20)\times 6}{2}\times\left(\frac{3}{2}+\frac{3}{2}\right)\right]$$

$$= 112500 + 1620$$
$$= 114120 \text{ mm}^3$$
$$= 114.1 \text{ cm}^3$$

20. (b)

The principal moment of inertia may be calculated by

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

$$= \frac{2\times10^7+0.97\times10^7}{2} \pm \sqrt{\left(\frac{2\times10^7-0.97\times10^7}{2}\right)^2 + \left(-0.83\times10^7\right)^2}$$

$$= 1.485\times10^7 \pm \sqrt{0.265225\times10^{14}+0.6889\times10^{14}}$$

$$= 1.485 \times 10^7 \pm 0.977 \times 10^7$$

$$I_{uu} = (1.485 + 0.977) \times 10^7 = 2.462 \times 10^7 \text{ mm}^4$$

$$I_{vv} = (1.485 - 0.977) \times 10^7 = 0.508 \times 10^7 \text{ mm}^4$$

$$\therefore \quad I_{min} = I_{vv} = 0.508 \times 10^7 \text{ mm}^4$$

$$\therefore \quad r_{min} = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{0.508\times10^7}{5025}} = 31.8 \ mm$$

Effective length of the strut or l_{eff} = 4.5 m

$$\therefore \quad \lambda = \frac{l_{eff}}{r_{min}} = \frac{4.5\times10^3}{31.8} = 141.51$$

$$\Rightarrow \quad \sigma_{ac} = 51 + \frac{45-51}{150-140}\times(141.51-140)$$

$$= 50.094 \text{ MPa}$$

∴ Load on the member

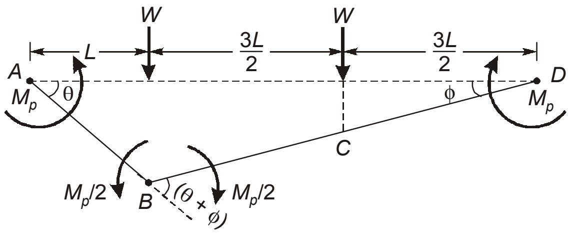
$$= \sigma_{ac} A$$

$$= 50.094 \times 5025 \times 10^{-3}$$

$$= 251.72 \text{ kN}$$

21. (d)

Collapse mechanism-I



$$\because \quad L\theta = 3L \times \phi$$

$$\Rightarrow \quad \theta = 3\phi \qquad \text{...(i)}$$

$$\text{Internal work done} = M_p\theta + \frac{M_p}{2}(\theta+\phi) + M_p\phi = 6M_p\phi$$

$$\text{External work done} = W\theta\times L + W\times\frac{3L}{2}\phi = 4.5\, WL\phi \qquad \text{...(ii)}$$

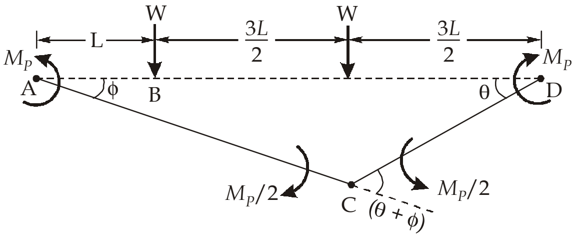
By eq. (i) and eq. (ii)

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

$$4.5\,WL\phi = 6\,M_p\phi$$

$$W_{u_1} = \frac{4}{3}\left(\frac{M_p}{L}\right)$$

Collapse mechanism-II



$$\because \quad \frac{5L}{2}\phi = \frac{3L}{2}\theta$$

$$\Rightarrow \quad 5\phi = 3\theta \qquad \text{...(iii)}$$

$$\text{External work done} = WL\phi + W\times\frac{3L}{2}\theta = 3.5\,WL\phi \qquad \text{...(iv)}$$

$$\text{Internal work done} = M_P\phi + \frac{M_P}{2}(\theta+\phi) + M_P\theta = 4M_p\phi$$

By eq. (iii) and eq. (iv)

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

$$\Rightarrow \quad 3.5\,WL\phi = 4M_p\phi$$

$$\Rightarrow \quad W = W_{u_2} = \frac{4}{3.5}\frac{M_P}{L} = \frac{8}{7}\frac{M_P}{L}$$

∴ Collapse load is $\frac{8}{7}\frac{M_P}{L}$ [Minimum of W_{u_1} and W_{u_2}]

22. **(c)**

23. **(c)**

$$\text{Web bearing strength} = \left[b + 2.5\left(t_f + R\right)\right]\times t_w \times \frac{f_y}{\gamma_{m0}}$$

$$= \left[70 + 2.5(22+10)\right]\times 10 \times \frac{210}{1.1}\times 10^{-3}\ \text{kN}$$

$$= 340.91\ \text{kN}$$

24. **(b)**

$$t = \sqrt{2.5w\left(a^2 - 0.3b^2\right)\times\frac{\gamma_{m0}}{f_y}}$$

a = larger projection = $\frac{460-300}{2}$ = 80 mm

$$b = \text{smaller projection} = \frac{400-250}{2} = 75 \text{ mm}$$

$$\therefore \qquad t = \sqrt{2.5\times 8.8\times\left(80^2-0.3\times 75^2\right)\times\frac{1.1}{250}}$$

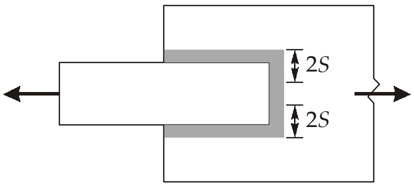
$$\Rightarrow \qquad t = 21.36 \text{ mm} \simeq 22 \text{ mm (say)}$$

So provide $t = 22$ mm

25. **(c)**

26. **(a)**

Refer **IS 800 : 2007 Clause 10.5.1.1 and 10.5.4.1**.



27. **(a)**

$$\text{Elastic section modulus, } Z_e = \frac{13158.3\times 10^4}{\frac{350}{2}} = 751.9\times 10^3 \text{ mm}^3$$

$$\text{Plastic section modulus, } Z_p = \text{S.F.} \times Z_e = 1.12 \times 751.9 \times 10^3$$

$$= 842.13 \times 10^3 \text{ mm}^3$$

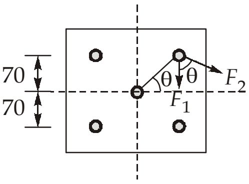
$$M = \left.\begin{matrix} \beta\cdot Z_p\cdot\dfrac{f_y}{\gamma_{m0}} \\ 1.2\,Z_e\cdot\dfrac{f_y}{\gamma_{m0}} \end{matrix}\right\} \text{whichever is less}$$

$\because \quad \beta = 1$ for compact section

$$\therefore \qquad M = \left\{\begin{matrix} 1\times 842.13\times 10^3\times\dfrac{250}{1.1}\times 10^{-6} = 191.39 \text{ kN-m} \\ 1.2\times 751.9\times 10^3\times\dfrac{250}{1.1}\times 10^{-6} = 205.06 \text{ kNm} \end{matrix}\right\} \text{minimum}$$

So, $\qquad M = 191.39$ kNm

28. **(d)**



$$F_1 = \frac{120}{5} = 24 \text{ kN}$$

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

$$= \frac{120 \times 0.5 \times \left(70\sqrt{2} \times 10^{-3}\right)}{\left(70 \times \sqrt{2}\right)^2 \times 4 \times 10^{-6}} = 151.52 \text{ kN}$$

$$\theta = 45°$$

$$F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$= \sqrt{24^2 + 151.52^2 + 2 \times 24 \times 151.52 \times \cos 45°}$$

$$= 169.34 \text{ kN}$$

29. (d)

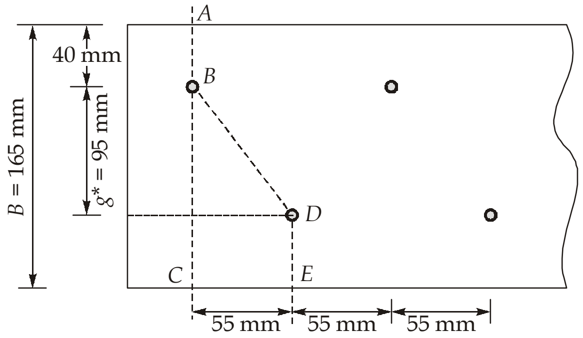
Diameter of bolt, $d = 18$ mm

∴ Diameter of bolt hole, $d_o = 18 + 2 = 20$ mm

Since both the legs of the angle section are connected and thus for calculating the net area of the angle section, the outstanding leg of the angle may be rotated and the total section may be visualized as a plate, as shown in figure below.

$$g^* = g_1 + g_2 - t = 60 + 45 - 10 = 95 \text{ mm}$$

Width of equivalent plate, $B = 100 + 75 - 10 = 165$ mm



Along ABC, $A_{n1} = (B - nd_o)t = (165 - 1 \times 20) \times 10 = 1450 \text{ mm}^2$

Along, A-B-D-E, $A_{n2} = \left(B - nd_o + \frac{n'p^2}{4g}\right)t$

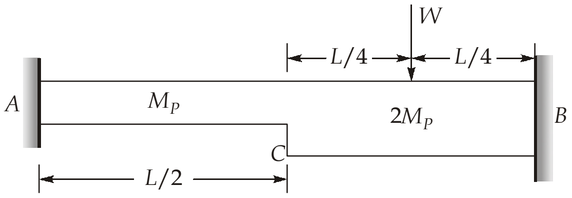
$n = 2$, $n' = 1$, $p = 55$ mm, $g = 95$ mm,

∴ $$A_{n2} = \left(165 - 2 \times 20 + \frac{(55)^2}{4 \times 95}\right) \times 10 = 1329.6 \text{ mm}^2$$

The minimum of A_{n1} and A_{n2} will be the net area of the section. Since both the legs of the angle sections are connected, the net area thus found will be the effective net area.

Hence, effective net area = 1329.6 mm $\simeq$ 1330 mm^2

30. **(c)**



Degree of static indeterminacy, $D_s = 2$

∴ No. of plastic hinges required for collapse,

$$n = D_s + 1 = 3$$

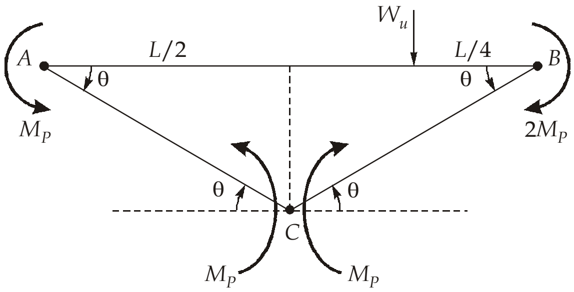
Possible location of plastic hinges are at A, B, C and under the load,

∴ $N = 4$

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

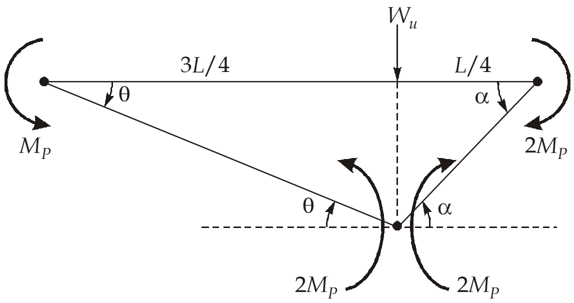
$$W_i = W_E$$

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

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

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

$$W_i = W_E$$

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

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

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

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

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