CLASS TEST

S.No.:01_CE_DEF_26082024

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Design of Steel Structures

CIVIL ENGINEERING

Date of Test : 26/08/2024

ANSWER KEY

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

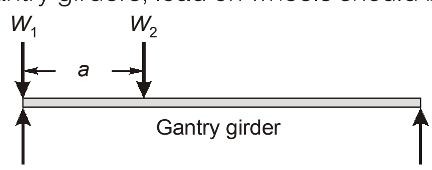
DETAILED EXPLANATIONS

1. (b)

As I_{yy} of combination is less than I_{xx} of combination, face to face arrangement will be better because it will lead to larger I_{min} for a given spacing.

3. (c)

For maximum shear force in gantry girders, load on wheels should be as close as possible.



where, W_1 and W_2 are wheel loads

6. (b)

Plastic section can develop plastic moment resistance and plastic hinge, but compact section can reach upto plastic moment of resistance and cannot make plastic hinge.

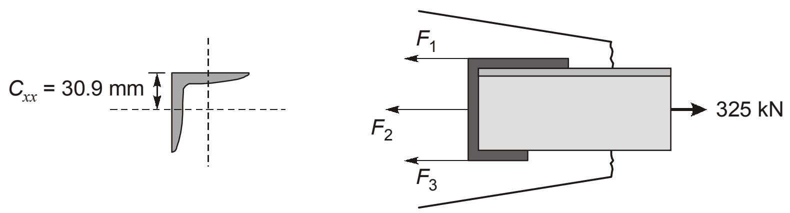
7. (d)

Wind-induced oscillations come under limit state of serviceability.

8. (b)

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

11. (d)



$$F_1 + F_2 + F_3 = 325 \text{ kN}$$
$$F_2 = \frac{350 \times 110}{1000} = 38.5 \text{ kN}$$
$$\Rightarrow \quad F_1 + F_3 = 286.5 \text{ kN} \quad \text{...(i)}$$

For no torsional moment to develop,

$$F_1(30.9) - F_3(110 - 30.9) - F_2(55 - 30.9) = 0 \quad \text{...(ii)}$$

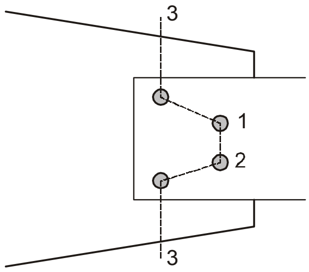
Solving (i) and (ii)

$$F_1 = 214.45 \text{ kN}$$

12. (a)

$$P = \frac{f_u}{\sqrt{3}\,\gamma_{mw}} \times t \times l$$
$$100 \times 10^3 = \frac{410}{\sqrt{3} \times 1.25} \times (0.707 \times 5) \times l$$
$$\therefore \quad l = 149.38 \text{ mm}$$

13. (d)



$$A_{\text{net 3-1-2-3}} = \left(360 - 4\times 20 + 2\times\frac{60^2}{4\times 60}\right)\times 10$$

$$A_{\text{net 3-1-2-3}} = 3100 \text{ mm}^2$$

$$A_{\text{net 3--3}} = (360 - 2\times 20)\times 10 = 3200 \text{ mm}^2$$

So, $$A_{\text{net minimum}} = 3100 \text{ mm}^2$$

14. (a)

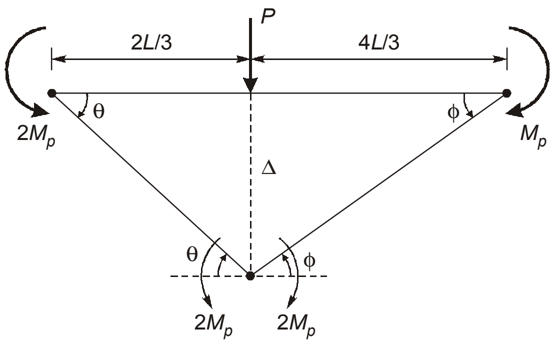
15. (a)

$$D_s = 2$$

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

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

Mechanism-1



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

$\Rightarrow$ $$\theta = 2\phi$$

By principle of critical work done,

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

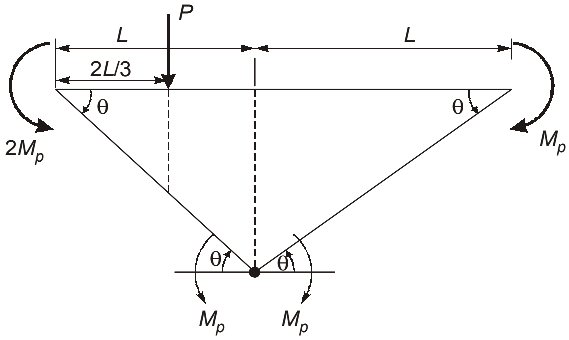
$\Rightarrow$ $$4\,M_p\theta + 3\,M_p\phi = \frac{2PL}{3}\theta$$

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

$\Rightarrow$ $$P_u = \frac{33M_p}{4L}$$

$\Rightarrow$ $$P_u = 8.25\,M_p/L$$

Mechanism-2



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

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

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

So, $$P_u = \text{Min}\left(\frac{7.5\,M_p}{L}, \frac{8.25\,M_p}{L}\right) = \frac{7.5\,M_p}{L}$$

16. (c)

$$I_{xx} = 2(I_{xx})_{\text{only}} = 54.4 \times 10^4 \text{ mm}^4$$

$$I_{yy} = 2[(I_{yy})_{\text{one}} + A_{\text{one}}\,[C_{yy} + s/2]^2$$

$$= 2[8.8 \times 10^4 + 552[10.4 + s/2]^2$$

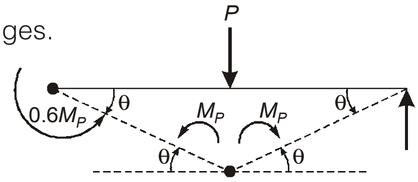
$$I_{xx} = I_{yy}$$

$$27.2 \times 10^4 = 8.8 \times 10^4 + 552\,(10.4 + s/2)^2$$

$$\therefore \quad s = 15.7 \text{ mm}$$

17. (a)

Failure in the left/right span can be caused by formation of two hinges.



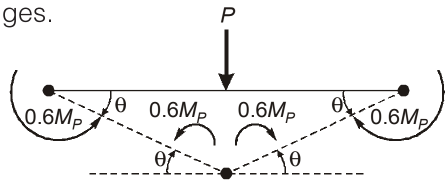
(Right Span)

Using virtual work method

$$\Rightarrow \quad P\cdot\frac{L}{2}\theta = M_P\cdot(2\theta) + 0.6M_P\cdot\theta$$

$$\Rightarrow \quad P = \frac{5.2M_P}{L}$$

The failure in the middle span will be caused by formation of 3 hinges.



(Middle Span)

$$\Rightarrow \quad P\cdot\frac{L}{2}\cdot\theta = 0.6M_P(\theta + 2\theta + \theta)$$

$$\Rightarrow \quad P = \frac{4.8M_P}{L}$$

Hence, collapse load is the minimum of the above two values, i.e. $\frac{4.8M_P}{L}$.

18. (c)

For Fe410 grade steel, $f_y = 250$ MPa

$\therefore$ Shear area $(A_v) = ht_w = 300 \times 7.5 = 2250$ mm^2

$\therefore$ Design shear strength of the beam section $= \dfrac{f_{yw}A_v}{\gamma_{m0}\sqrt{3}}$

$$= \frac{250 \times (300 \times 7.5)}{1.1 \times \sqrt{3}} = 295235.93\text{N} = 295.236 \text{ kN}$$

19. (b)

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

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

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

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

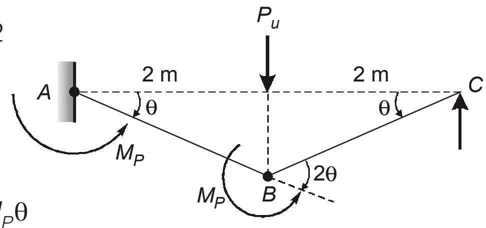
21. (a)

Degree of static indeterminacy = 1

$\therefore$ Number of plastic hinges required for collapse = 1 + 1 = 2

At failure,

Plastic hinges form at A and B



$$\text{External work} = P_u \times 2\theta = 2P_u\theta$$

$$\text{Internal work} = M_P\theta + M_P \times 2\theta = 3M_P\theta$$

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

$$\Rightarrow \quad 2P_u\theta = 3M_P\theta$$

$$\Rightarrow \quad P_u = \frac{3}{2} \times 100 = 150 \text{ kN}$$

22. (b)

$$\text{Size of the weld} = 8 \text{ mm}$$

$$\therefore \quad \text{Throat thickness, } t = 0.7 \times 8 = 5.6 \text{ mm}$$

$$\text{Vertical shear stress in weld } (f_s) = \frac{W}{2 \times d \times t} = \frac{100 \times 10^3}{2 \times 300 \times 5.6} = 29.76 \text{ MPa}$$

Maximum bending stress will be at the extreme points,

$$f_b = \frac{6We}{2td^2} = \frac{6 \times 100 \times 10^3 \times 50}{2 \times 5.6 \times 300^2} = 29.76 \text{ MPa}$$

$$\therefore \quad \text{Maximum resultant stress} = \sqrt{f_s^2 + f_b^2} = \sqrt{29.76^2 + 29.76^2} = \sqrt{2} \times 29.76 = 42.09 \text{ MPa}$$

23. (b)

$$\text{Total weld length} = 250 \times 2 + 80 = 580 \text{ mm}$$

$$\text{Strength of weld} = 0.7 \times 8 \times 108 = 604.8 \text{ N/mm}$$

$$\text{Maximum load} = 604.8 \times 580 \times 10^{-3} \simeq 350.78 \text{ kN}$$

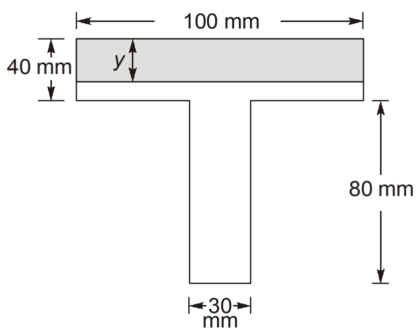
25. (a)

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

So,

Calculation of location of equal area axis

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



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

$$\therefore \quad \text{Compressive force} = \text{Area} \times \text{Stress} = (32 \times 100) \times 250 = 800 \text{ kN}$$

26. (b)

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

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

∴ Design compressive strength,

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

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

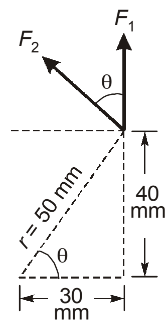
$$F = 70.112 \times 8591 \times 10^{-3} = 602.3 \text{ kN}$$

27. (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.

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

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



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

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

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

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

$$= 0.64P \le 45$$

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

28. (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.

29. (c)

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

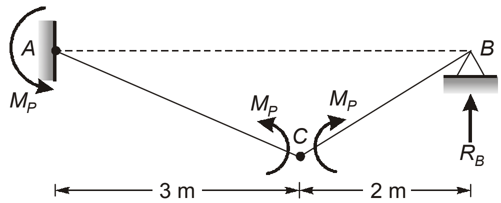
d_h = diameter of rivet hole, p = pitch

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

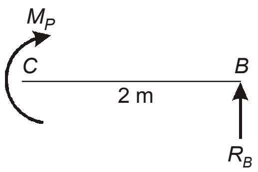
∴ $\eta = 1 - 0.25 = 0.75$

or $\eta = 75\%$

30. (d)



Portion *BC*



⇒ $M_P = 2 \times R_B$

⇒ $60 = 2 \times R_B$

⇒ $R_B = 30 \text{ kN}$

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