CIVIL ENGINEERING

GATE | PSUs

STEEL STRUCTURES

Volume - I : Study Material with Classroom Practice Questions

Steel Structures

Solutions for Volume : I Classroom Practice Questions

Chapter- 2
Riveted Connections

Class Room Practice Questions

01. Ans: 60%

Sol: $\eta = \dfrac{p-d}{p} \times 100$

$p_{min} = 2.5\phi$

$d = \phi + 1.5$

$= \dfrac{2.5\phi - \phi}{2.5\phi} \times 100$

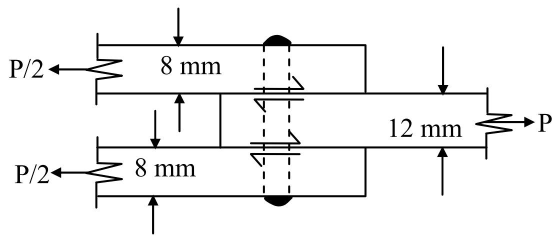
$= \dfrac{1.5\phi}{2.5\phi} \times 100$

$\eta = 60\%$

02. Ans: (c)

05. Ans: (43.29)

Sol:



Nominal dia of rivet (ϕ) = 16 mm

For field Rivets permissible shear stress in Rivet .

$\tau_{vf} = 90$ MPa

Bearing stress in Rivet $\sigma_{pf} = 270$ MPa

Rivet value

R_v = lesser of P_s & P_b

$\phi = 16$ mm ($\phi \le 25$ mm)

$d = \phi + 1.5 = 17.5$ mm

$P_s = 2 \times \dfrac{\pi}{4}(d)^2 \times \tau_{vf}$

$= 2 \times \left(\dfrac{\pi}{4}\right)(17.5)^2 \times 90$

$P_s = 43.29 \times 10^3$ N

$= 43.29$ kN

Bearing strength of one rivet

$P_b = d \times t \times \sigma_{pf}$

$= 17.5 \times 12 \times 270$

$P_b = 56.7$ kN

R_v = lesser of P_s & P_b

$\therefore \quad R_v = 43.29$ kN

t (MP) = 12 mm

t (cp + cp) = 8 + 8 = 16 mm

06. Ans: (d)

Sol: No. of rivets $n = \dfrac{P}{P_r\,(\text{or})\,R_v} = \dfrac{200}{40} = 5$

$$P_s = 2\times\frac{\pi}{4}(d)^2\times\tau_{vf} = 80\,\text{kN}$$

$$P_s = \frac{\pi}{4}d^2\times\tau_{vf} = 40\,\text{kN}$$

$P_s = 40$ kN, $P_b = 60$ kN, $P_{tr} = 70$ kN

$$n = \frac{P}{P_s} = \frac{200}{40} = 5$$

10. Ans: (d)

Sol: Minimum pitch of rivets in compression zone

$$\left.\begin{matrix}12\,t\,\text{mm}\\200\,\text{mm}\end{matrix}\right\}\text{ whichever is minimum}$$

t = 10 mm

12t = 12 × 10 = 120 mm

=200 mm

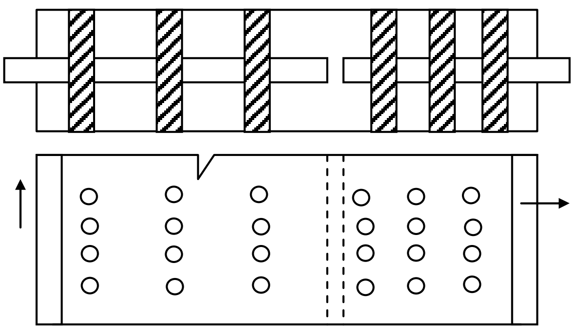
Pitch = 120 mm

Design of Simple bolted connection

Class Room Practice Questions

05. Ans: (d)

Sol:



$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}(n_n A_{nb} + n_s A_{sb})$$

n_n (or) n_s

= 3 × 2 = 6

06. Ans: (b)

Sol: P = 240 kN; V_{dsb} = 40 kN; V_{dpb} = 50 kN;

T_{db} = 30 kN; V_{db} = lesser of V_{dsb}, V_{dpb}

$$n = \frac{P}{V_{db}} = \frac{240}{40}$$

n = 6 no's

07. Ans: (d)

Sol: Tensile force in each bolt due to $P_4\cos\theta$

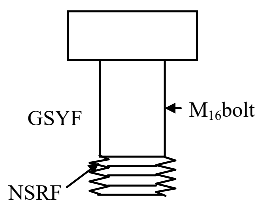
$$T_b = \frac{P_4\cos\theta}{n} = \frac{250}{6}\times\frac{4}{5} = 33.33\text{ kN}$$

Shear force in each bolt due to $P_4\sin\theta$

$$V_b = \frac{P_4\sin\theta}{n} = \frac{250}{6}\times\frac{3}{5} = 25\text{ kN}$$

08. Ans: (d)

Sol:



For M_{16} bolt d = 16 mm

For Grade 4.6; f_{ub} = 400 MPa

f_{yb} = 240 MPa

Design tensile strength of bolt T_{db} = ?

T_{db} is based on Gross section

$$T_{db_1} = \frac{A_{sb} f_{yb}}{\gamma_{mo}}$$

$$T_{db_1} = \frac{\frac{\pi}{4} \times (16)^2 \times 240}{1.1}$$

$$= 43.86 \times 10^3 \text{ N}$$

T_{bd} is based on net section rupture

$$T_{db_2} = \frac{0.9 A_{nb} f_{ub}}{\gamma_{mb}}$$

$$= \frac{0.9(0.78 \times \frac{\pi}{4} \times (16)^2 \times 400)}{1.25}$$

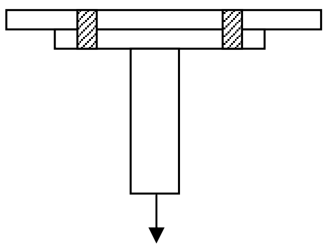
$$T_{db_2} = 45 \times 10^3 \text{ N}$$

T_{db} is lesser of T_{db_1} & T_{db_2}

$\therefore$ T_{db} = 43.86 kN

09. Ans: (c)

Sol: Hanger connection looks like this one



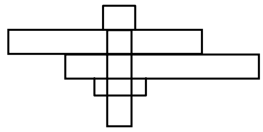
In hanger connections bolts experience only tensile stress. Then we clearly taken, Strength of rivet is equal to the design strength of bolt in tension.

$\overline{P}_{db} = 45 \text{kN}$ = Design bolt strength

Number of bolts required = 180 kN/45 kN = 4 no

10. Ans: (b)

Sol: Design strength values



V_{dpb} = 1,50,000 N

T_{dp} = 1,80,000 N

T_{sp} = 2,40,000 N

V_{dsb} = 1,60,000 N

$$\eta = \frac{V_{dc}}{T_{sp}} \times 100$$

$$V_{dc} \text{ is lesser of } \begin{pmatrix} V_{dsp} & T_{db} \\ V_{dpb} & T_{dp} \end{pmatrix}$$

$$= \frac{1,50,000}{2,40,000} \times 100 = 62.5\%$$

η = 62.5%

Chapter- 3
Welded Connections

Class Room Practice Questions

05.

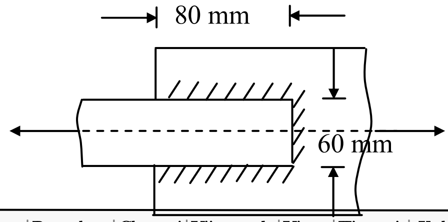
Sol: $f_s = \frac{f_s}{\sqrt{3} \times (\gamma_m)}$

γ_m = 1.25 welding in done in slop

= 1.5 welding is done in 'field'.

06. Ans: (d)

Sol:



$S = 8$ mm, $\tau_{vF} = 110$ N/mm^2

Working stress method $\Rightarrow$

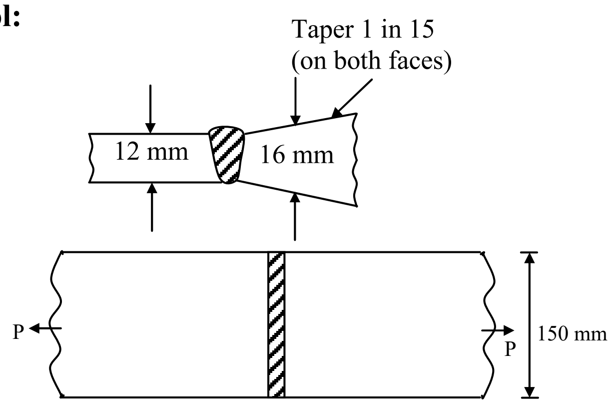
$\therefore \quad P_s = L_w \times t_t \times \tau_{vf}$

$= (80+80+60) \times (0.7 \times 8) \times 110$

$= 135$ kN

07. Ans: (a)

Sol:



Single 'V' butt weld

Given data:

Permissible tensile stress in the plate

$\sigma_{at} = 150$ MPa

What is maximum tension P =?

We can allow Maximum tension load up to strength of butt weld

= Axial strength of butt weld

$P = T_s = l w.t_e.\sigma_{tf}$

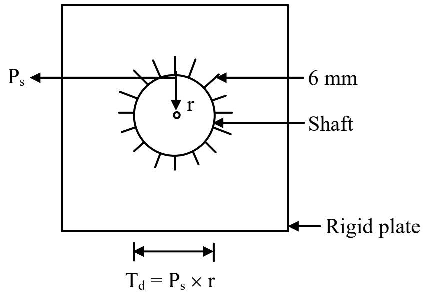
$$= 150 \times \frac{5}{8} \times 12 \times 150$$

$= 168.78 \times 10^3$N

$P = 168.75$ kN

08. Ans: (b)

Sol:

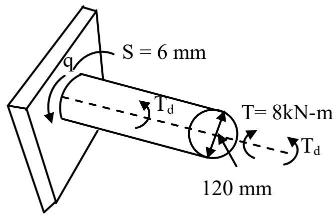


Size of weld (S) = 6 mm

Torque $T = 8$ kN-m

$= 8 \times 10^6$ N-mm

Maximum stress in weld q =?



Twisting moment capacity of weld

$$T_d = P_s \times r = P_s \times \frac{d}{2}$$

$$= L_w.t_t.q.\frac{d}{2}$$

$$T = \pi d(ks)q.\frac{d}{2}$$

$$8 \times 10^6 = \pi \times 120 \times (0.7 \times 6) \times q \times \frac{120}{2}$$

$q = 84$ N/mm$^2 \simeq 85$ MPa

09. Ans: (b)

Sol:

$S = 10$ mm; $f_y = 250$ Mpa $= f_yw$; $f_u = 410$ Mpa;

$\gamma_{mw} = 1.25$; $P = 270$ kN

$= f_{yw}$

$\therefore \quad L_w = l_j + l_j = 2l_j$

$$P \le P_{dw} = L_w \times t_t \times \frac{f_u^1}{\sqrt{3}\gamma_{wm}}$$

$$\Rightarrow \quad 270\times10^3 = (2\times\ell_j)\times(k\times S)\times\frac{f_u^1}{\sqrt{3}\gamma_{mw}}$$

$$\Rightarrow 270\times10^3 = (2\times\ell_j)\times(0.7\times10)\times\frac{410}{\sqrt{3}\times1.25}$$

$l_j = 101.6$ mm

$l_j \simeq 105$ mm

10. Ans: 60

Sol: Throat thickness = 0.7× 6 mm
= 4.2 mm
Effective length of weld = 100 + 100 +50
= 250 mm

Permissible stress in the weld = 150 MPa
Strength of weld = (4.2×250] ×150 N
= 115.5 kN
Strength of plate= [50 × 8] ×150 N
= 60 kN
Then before the failure of weld joint plate fails.
The permissible load allowable = 60 kN

Chapter- 4
Eccentric Connections

Class Room Practice Questions

02. Ans: (a)

Sol:

r = Max (1, 3, 4 & 6) θ = min (1)

Hence critical bolt is Bolt No. 1

03. Ans: (b)

Sol:

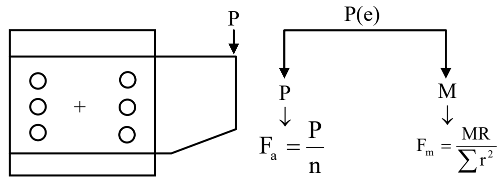
$$\left(\frac{V_b}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \le 1.0$$

$x^2 + y^2 = r^2 \quad (r = 1)$

It is circle equation

04. Ans: (c)

Sol:



(1) $F_a \propto r$ (2) $F_m \propto r$

(3) $F_a < 0.5\ V_{db}$ (4) $F_m \le r$

05. Ans:5.99

Sol: Given load P = 10 kN
Eccentricity = 150 mm
Number of rivets =4

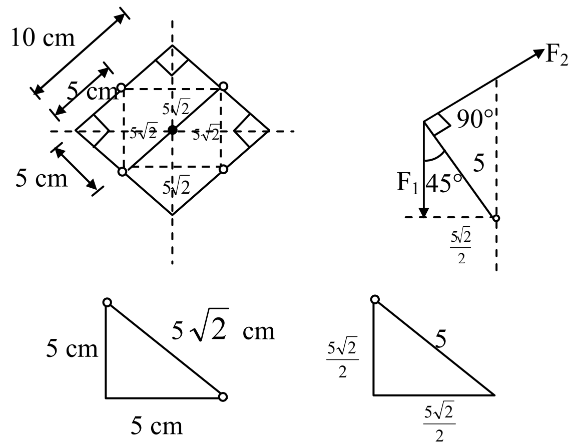
Force in rivet 1 due to direct loading = $\frac{P}{4}$

$F_1 = 2.5$ kN

Force in rivet 1 due to twisting moment

$$= \frac{M.r_e}{Er_i^r}$$

M = P[150] kN-mm



$$F_2 = \frac{[10]\times 150\times 50}{4\times[50]^2} = 7.5 \text{ kN}$$

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

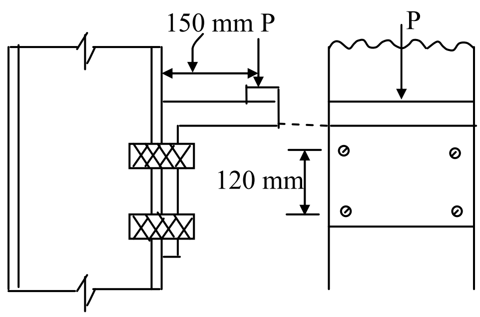
$\theta = 135°$

$F_R = 5.99$ kN

06. Ans: (c)

Sol: Design shear stress $V_{db} = 20$ kN

Design tensile capacity $\tau_{bd} = 15$ kN



1) P → cause shear force in bolt= P/ 8n.

2) M = P × e = P × 150

= 150P kN − mm.

$$V_b = \frac{P}{n} = \frac{P}{4}$$

$$\frac{M}{I} = \frac{f}{y}$$

$$f = \left(\frac{M}{I}\right)y$$

$$T_b = f.\,A = \frac{M}{I}y.A$$

M = 150 P kN − mm

$$y = \frac{120}{2} = 60\text{mm}$$

$$I_{XX} = [I_{CG} + Ag\,]4$$

$$= \left[\frac{\pi d^4}{64} + A(60)^2\right]4 \qquad \left(\frac{\pi d^4}{64}\text{ neglected}\right)$$

because it is very smaller than (60^2) A.

$= 14400$ A mm^4

$$T_b = \frac{M}{I}\times y\times A$$

$$= \frac{150P}{14400A}\times 60\times A = \frac{5P}{8}$$

Interaction formula

$$\left(\frac{V_b}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \le 1.0$$

$$= \left(\frac{P}{4}\times\frac{1}{20}\right)^2 + \left(\frac{5P}{8}\times\frac{1}{15}\right)^2 \le 1.0$$

$$\left(\frac{P}{80}\right)^2 + \left(\frac{P}{24}\right)^2 \le 1.0$$

07. Ans : 156.20

Sol: An eccentric load may be replaced by set of one direct concentric load (p) and in plane moment (M)

$$M = p.e$$
$$= (100)\,(600)$$
$$= 6 \times 10^4 \text{ kN-mm}$$

Force in each bolt due to direct concentric load (F_a)

$$F_a = \frac{p}{n} = \frac{100}{5} = 20\text{kN}$$

Force in critical bolt due to moment (F_m)

$$= \frac{p.e.r}{r^2}$$
$$= \frac{M.r}{\Sigma r^2} = \frac{6\times10^4 \times 75\sqrt{2}}{4\times\left(75\sqrt{2}\right)^2 + 0}$$
$$= \frac{6\times10^4\times75\sqrt{2}}{4\times75^2\times2}$$
$$= 141.42 \text{ kN}$$

Maximum Resultant force in critical bolt 1 and 2 is

$$F_{Rmax} = \sqrt{F_m^2 + F_a^2 + 2F_aF_m\cos\theta}$$
$$= \sqrt{(141.42)^2 + (20)^2 + 2\times20\times(141.42)\times\left(\frac{1}{\sqrt{2}}\right)}$$
$$= 156.20 \text{ kN}$$

08. Ans: 20 kN

Chapter- 5
Tension Members

Class Room Practice Questions

01. Ans: 240

Sol: $f_y = 400$ MPa

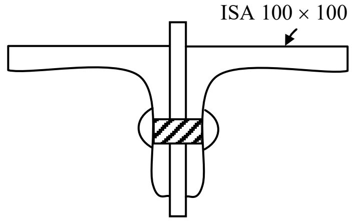
Permissible tensile stress (σ_{at}) = $0.6 \times f_y$

$= 0.6 \times 400$

$\sigma_{at} = 240$ MPa

02. Ans: (d)

Sol:



ISA = 100 × 100 × 10

$A_1 = 775 \text{ mm}^2$

$A_2 = 950 \text{ mm}^2$

$A_{net} = A_1 + A_2K_1$

$$K_1 = \frac{3A_1}{3A_1 + A_2} = \frac{3\times775\times2}{(3\times775+950)^2} = 0.709$$

K_1 = Reduction factor = 0.709

$A_{net} = A_1 + A_2 \times K_1$

$= (2\times775) + (2\times950)\times0.709$

$A_{net} = 2899 \text{ mm}^2$

03. Ans: (c)

Sol:

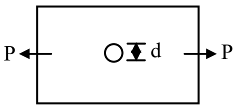


Fig. 1

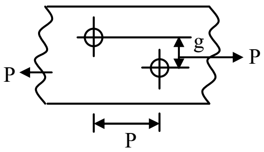


Fig. 2

$$P_t = A_{net} \times \sigma_{at}$$

($\sigma_{at} = 0.6\, f_y$ is same (1) & (2)

$P_t \propto A_{net}$

$$P_{(t)_2} > P_{t_{(1)}}$$

$$A_{net(2)} > A_{net(1)}$$

$$(B-2d)t + \frac{P^2 t}{4g} > (B-d)t$$

$$Bt - 2dt + \frac{P^2 t}{4g} > Bt - dt$$

$$-dt - dt + \frac{P^2 t}{4g} > -dt$$

$$\frac{P^2 t}{4g} > dt$$

$\Rightarrow \quad P^2 > 4gd$

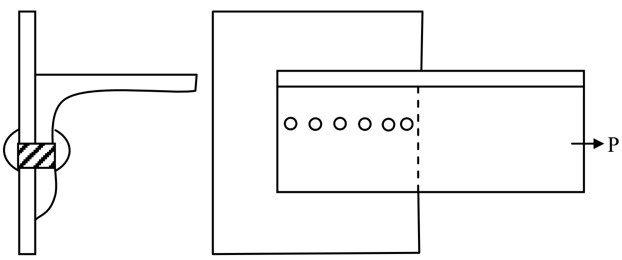
04. Ans: (d)

Sol:

ISA: 100 × 100 × 10

$\sigma_{at} = 150$ N/mm^2

Nominal dia of rivet $\phi = 20$ mm



Gross dia (d) = $\phi + 1.5$

= 21.5 mm ($\phi = 20$ mm)

Safe tensile strength = $(P_t) = A_{net} \times \sigma_{at}$

$A_{net} = A_1 + A_2K_1$

$A_1 = (x - d - t/2)\, t$

$$= \left(100 - 21.5 - \frac{10}{2}\right) 10$$

$= 735$ mm^2

$A_2 = (y - t/2)\, t$

$$= \left(100 - \frac{10}{2}\right)10$$

$= 950$ mm^2

$$K_1 = \frac{3A_1}{3A_1 + A_2} = \frac{3 \times 735}{3 \times 735 + 950}$$

$K_1 = 0.70$

$A_{net} = A_1 + A_2K_1$

$= 735 + 950 \times 0.70 = 1400$ mm^2

$P_t = A_{net} \times \sigma_{at} = 1400 \times 150$

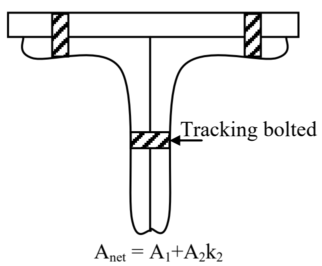
$P_t = 210$ kN

06. Ans: λ = 180

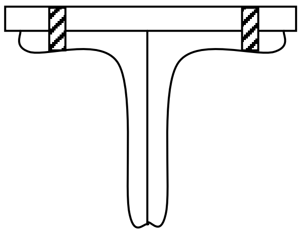
07. Ans: (c)

Sol:

(a)

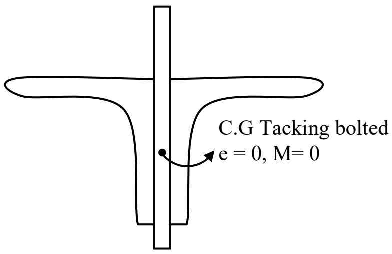


(b)



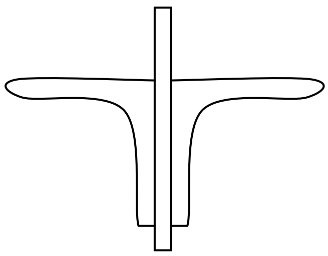
$A_{net} = A_1 + A_2k_2$

(c)



$A_{net} = A_g -$ Area of rivet hole

(d)



$A_{net} = A_1 + A_2k_1$

$$K_1 = \frac{3A_1}{3A_1 + A_2}; \quad K_2 = \frac{5A_1}{5A_1 + A_2}$$

$P_t = A_{net} \times A_{at}$

$w(a) = w(b) = w(c) = w(d)$

$A_{(c)net} > A_{net\,(a)} > A_{net\,(b)} = A_{net\,(d)}$

$\therefore \quad P_{(t)\,c} > P_{t(a)} > P_{t(b)} = P_{(t)d}$

08. Ans: (c)

Sol: $r_{min} = 200$ mm

Slenderness ratio of trial section $\le \lambda_{limit}$

$$\frac{\ell_{max}}{r_{min}} \le 350$$

$$\ell_{max} \le 350 \times r_{min}$$

$$\ell_{max} \le 350 \times 6`$$

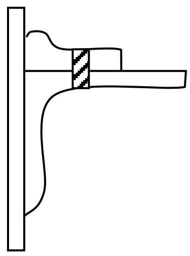
$\ell_{max} \le 2100$ mm (or) ≤ 7.0 m

$l_{max} = 2.10$ m

09. Ans: 40

Sol: $\eta_2 \times R_V = 1.40\ T_2$

$= 40\%$



10. Ans: (b)

Chapter- 6
Compression Members

Class Room Practice Questions

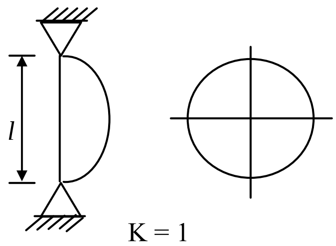
01. Ans: 50

Sol: KL = effective length

K = effective length constant

$$\left(\frac{KL}{r}\right) = 200$$

$$\frac{\ell}{d} = ?$$



Radius of gyration, $r_{min} = \sqrt{\frac{I}{A}}$

$$= \sqrt{\frac{\pi d^4}{64} \times \frac{4}{\pi d^2}}$$

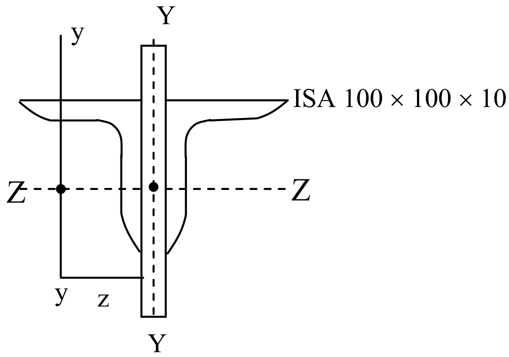
$$= \sqrt{\frac{d^2}{16}} = \frac{d}{4}$$

$$\frac{KL}{r_{min}} = \frac{1.0\ell}{\frac{d}{4}} = 200$$

$$\frac{\ell}{d} = \frac{200}{4} = 50$$

05. Ans: 30.6

Sol:



Symmetric w.r.t yy axis

$A = 1903 \text{ mm}^2$

$I_{zz} = I_{yy} = 177 \times 10^4 \text{ mm}^4$

$I_{yy} = 2\left(I_{yy} + Az^2\right)$

Gusset plates one at joint member only.

$I_{ZZ} = 2.I_{zz}$

$I_{min} = I_{ZZ}$

$$r_{min} = \sqrt{\frac{I_{ZZ}}{A}}$$

$$= \sqrt{\frac{2 \times 177 \times 10^4}{2 \times 1903}}$$

$= 30.49 \text{ mm} \simeq 30.5 \text{ mm}$

07. Ans: 37.5

Sol: V = 2.5% of factored column load

Service load = 1000 kN

Factored load = 1.5×1000

= 1500 kN

$$V = \frac{2.5}{100} \times P$$

$$= \frac{2.5}{100} \times 1500 = 37.50 \text{ kN}$$

08. Ans: (d)

Sol: Force in lacing member

$$F = \frac{V}{N\sin\theta}$$

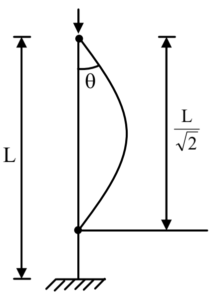
$$= \frac{37.5}{2\times\sin 45^0}$$

($\because$ N = 2 for single lacing system)

$= 26.52$ kN

09. Ans: (b)

Sol:

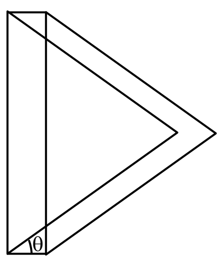


$$\frac{L}{\sqrt{2}} = 0.707\text{ L}$$

$= 0.80$ L

10. Ans: (d)

Sol:



Skin buckling

Chapter- 7
Column Bases & Column Splices

Class Room Practice Questions

02. Ans: 9

Sol: Bearing strength of concrete is = 0.45 f_{ck}

f_{ck} = 20 Mpa

$= 0.45 \times 20 = 9$ N/mm^2

03. Ans: (b)

Sol: We know that allowable bearing strength of

$$\text{concrete} = \frac{\text{factored load (P)}}{\text{area of base slab}}$$

Here maximum bearing strength = 0.45 f_{ck}

$$\therefore\ 0.45\ f_{ck} = \frac{2000\times10^3}{650\times420}$$

$\therefore$ $f_{ck} = 16.28$

$\therefore$ Minimum grade of concrete required

= M20

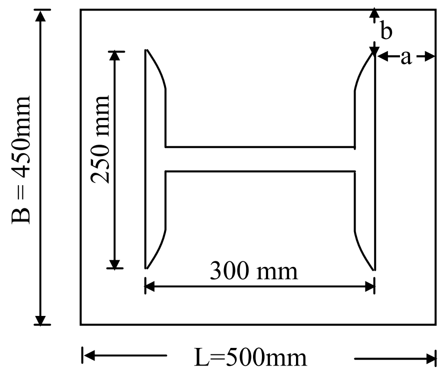
04. Ans: 26.3

Sol: $$t_s = \sqrt{\frac{2.5w\left(a^2 - 0.3b^2\right)\gamma_{mo}}{f_y}} > t_f$$

w = 9.0 N/mm^2;

t_f = 11.6 mm , b_f = 250 mm

D = 300 mm



$$a = \frac{500-300}{2}$$

$a = 100$

$$b = \frac{450-250}{2}$$

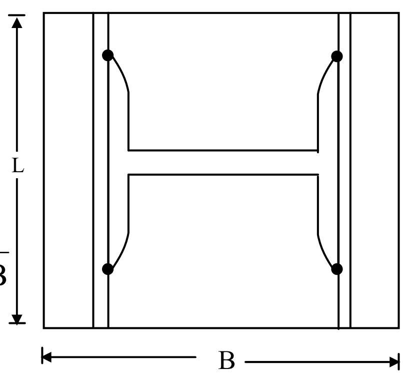
$b = 100$

$$t_s = \sqrt{\frac{2.5\times 9\times\left(100^2 - 0.3\times 100^2\right)\times 1.10}{250}}$$

$= 26.3$ mm $> t_f = 11.6$mm

05. Ans: (b)

Sol:



$$w = \frac{P}{L\times B}$$

$$t = C\sqrt{\frac{2.75\,w}{f_y}}$$

$$W = \frac{P}{L\times B}$$

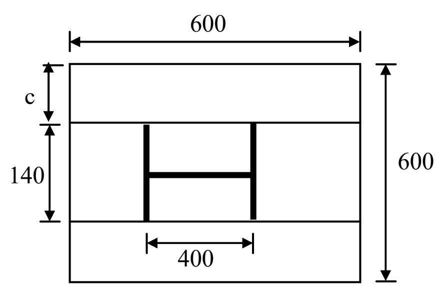
$\therefore$ If area$\uparrow$, the W$\downarrow$ then t$\downarrow$ but here area $\Rightarrow$ same

So $\sqrt{\dfrac{W}{f_y}} \Rightarrow$ constant for all options

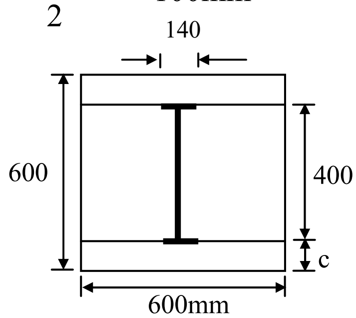
$\therefore$ t α c

Gusset plate to be provided along full width of base plate cantilever projection is available along length of base plate direction

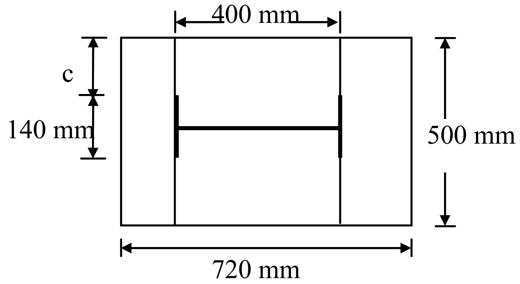
a) $c = \dfrac{600-140}{2} = 230\,\text{mm}$



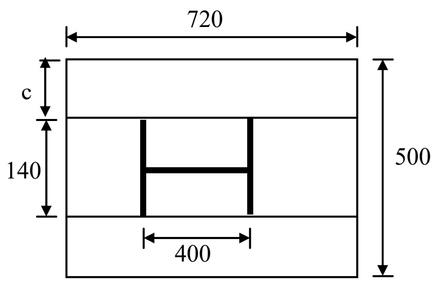
b) $c = \dfrac{600-400}{2}$ =100mm



c) $c = \dfrac{500-140}{2} = 180\,\text{mm}$

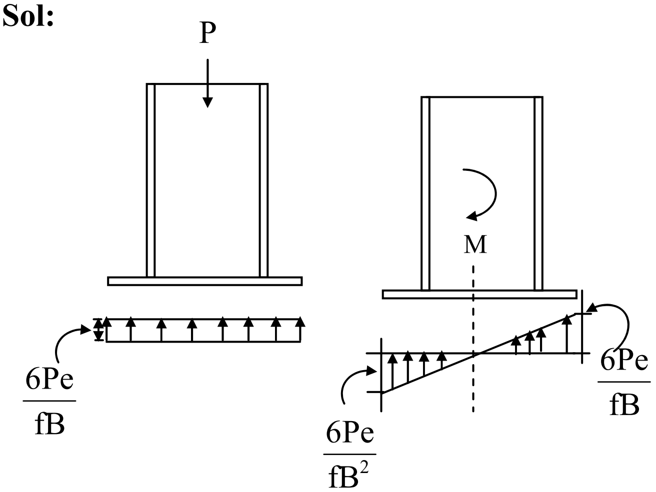


d) $c = \dfrac{720-400}{2} = 160\text{ mm}$



06. Ans: (d)

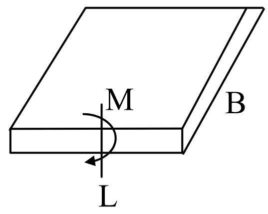
Sol:



$$\text{Bending stress} = \frac{M}{Z} = \frac{Pe}{\frac{BL^2}{6}} = \frac{6Pe}{BL^2}$$

$$\text{Combined stress} = \frac{P}{LB} \pm \frac{6Pe}{BL^2}$$

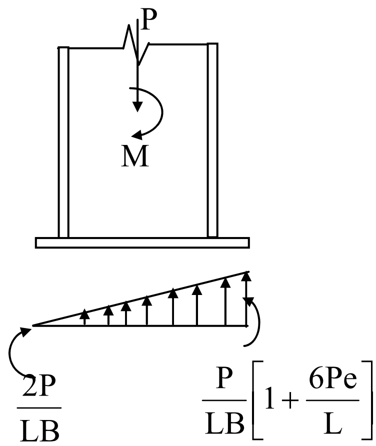
$$= \frac{P}{LB}\left[1 \pm \frac{6e}{L}\right]$$



$$Z = \frac{I}{y} = \frac{BL^3}{12} \times \left(\frac{2}{L}\right) = \frac{BL^2}{6}$$

$$= \frac{BL^2}{6}$$

$\therefore$ Zero at one end compression at other end.



Chapter- 8
Beams

Class Room Practice Questions

08. Ans: 100

Sol: $Z_e = 500\text{ cm}^3$, $Z_P = 650\text{ cm}^3$

Laterally unrestrained beam semi compact section

Design bending compressive stress $f_{bd} = 200$ MPa

The flexural (or) bending strength

$M_d = \beta_b .Z_p. f_{bd}$

$$= \frac{Z_e}{Z_P}.Z_p.f_{bd}$$

$$= 500\times10^3\times200 = 100\times10^6\text{ N-mm}$$

$M_d = 100$ kN-m

09. Ans : 669.2

Sol: The design shear capacity of I-section is given by $(V_d) = \dfrac{A_v \times f_{yw}}{\sqrt{3}\times\gamma_{mo}}$

$$(V_d) = \frac{(D\times t_w)\times f_{yw}}{\sqrt{3}\times\gamma_{mo}}$$

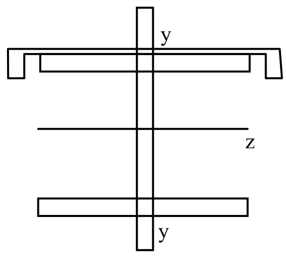
$$= \frac{(500\times10.2)\times250}{\sqrt{3}\times1.1} = 669.20\text{ kN}$$

Chapter- 10
Gantry Girders

Class Room Practice Questions

01. Ans: (a)

Sol:



$I_{yy} = (I_{yy\text{ of ISWB}} + I_{zz\text{ channel}})$