Notes by-

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Comp.
Beam
Footing
WPG
Beam: col

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COMPRESSION MEMBER

⇒ No bending of member

⇒ Truss : Compression member ⇒ Strut

Building : col^m or stanchions.

Crane : Boom.

Main comp. member in roof truss: Rafter.

$\sigma_{ac} = 80$ MPa → General member

$\sigma_{ac} = 110$ MPa → Heavy (Built up)

$\sigma_{at} = 150$ MPa

20 mm pds Rivet { σ_{tf} = Bearing strength = 300 MPa ; τ_{vt} = Shearing strength = 100 MPa }

* Comp. member rarely fails by crushing.
* Per. comp. strength is minimum for slender col^m; which can easily buckle under the compressive load.

* Strength of compression member :- [Axially loaded]

The max. axial compressive load 'P' which can be permitted on a comp. member is given by,

$$P = \sigma_{ac} \cdot A$$

Where, P = axial comp. load (N)

σ_{ac} = per. stress in axial comp. (MPa)

A = eff. c/s area of member. (mm^2)

= Gross c/s area − Deduction for holes not filled completely by rivets or bolts.

σ_{ac} can be calculated by [Merchant Rankine formula − Cl. 5.1.1]

or Table 5.1, Cl. 5.1.1, gives σ_{ac} depending on fy & [$\lambda = l_e / r_{min}$.]

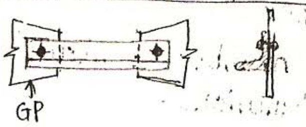
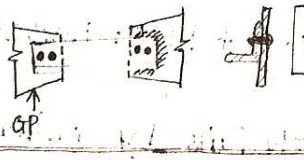
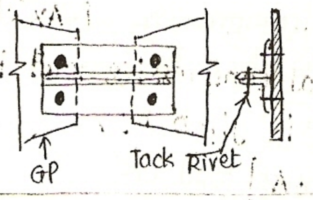
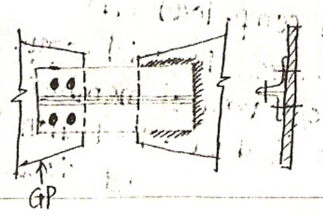
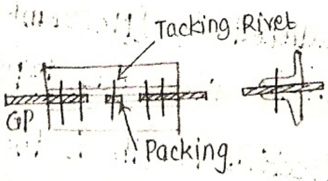
* Effective length :- Effective length is the length betⁿ point of contraflexure ; & when accurate frame analysis is not done, effective length can be directly obtained from [Table 5.2 / Cl. 5.2.2 / Pg. 41] depending on end conditions.

* Angle struts :- [Cl. 5.5 / Pg. 46]

For angle struts, design specifications are slightly different & Table on next page gives effective length, allowable stress & max. slenderness ratio for angle comp. member depending upon end conditions.

Types of angle strut :-
- ① Discontinuous
  - Single
    - single angle & one Rivet at each end
    - single angle two Rivet / Weld at each end
  - Double
    - Double angle, any No. of rivet or bolts or weld on both side of GP
    - Double angle, ~~any No. of rivet, weld, placed~~ on same side of GP
      - One No. of Rivet or bolt at each end
      - any No. of rivet or bolt or weld at each end.
- ② Continuous
  - single angle
  - double angle.

V. Imp **GATE** Angle strut (Cl. 5.5)

Sr. No.	Type	End condition		eff. length	allowable stresses
①	Single angle Discontinuous	a) one rivet or bolt at each end.		$l_e = L$	$0.8\,\sigma_{ac}$
		b) Two or more rivets or bolts or welding at each end.		$l_e = 0.85L$	σ_{ac}
②	Double angle discontinuous [Tacking Provided]	a) Connected on side side of GP i) One rivet or bolt at each end.		$l_e = L$	$0.8\,\sigma_{ac}$
		ii) Two ore more rivets, bolts or weld at each end.		$l_e = 0.85L$	σ_{ac}
		b) Connected on both sides of GP. by two or more rivets or bolts or welding.		$l_e = 0.7$ to $0.85\,l$. (Depending on rigidity of Joint)	σ_{ac}
③	Single or double angle Continuous	one or more rivet or bolt or welding.		$l = 0.7L$ to $0.85L$ (Depending on end rigidity)	σ_{ac}

One Rivet at each end ⇒ $\sigma_{ac} = 0.8\,\sigma_{ac}$, $l_e = L$; otherwise provide "σ_{ac}", $l_e = 0.85L$ ← short cut

L = Unsupported Length

σ_{ac} = Per. comp. stress (axial)

* **Truss** :- In case of bolted, riveted or welded trusses & braced frames, the effective length 'l' of comp. member is taken in betⁿ 0.7L to 1L (where L = dist. betⁿ intersection) depending upon degree of restraint [end conditions] provided.

In case of members of truss, buckling in the plane of truss ⊥ar or ⊥ar to the plane of truss, eff. length is taken as 1.0 times dist. betⁿ points of restraint.

(GATE) Max. slenderness Ratio:-

slenderness Ratio = $\lambda = \frac{le}{r_{min}}$ should not exceed :→

Sr. No.	Member	λmax.
①	Member carrying comp. load (DL+LL or superimposed load)	180
②	Tension member; Reversal of stresses due to load other than WL & EQ loads	180
③	Comp. member due to WL & EQ load (provided that deformat^n of such member does not adversly affect the stress in any part of the str.)	250
④	Comp. flange of a beam	300
⑤	Tie member in roof truss or Bracing system [subjected to possible reverse of stress due to WL & EQ load]	350
⑥	Tension member (except - pretensioned)	400

* Compression member :- Two components Back To Back :- [cl. 5.9 & 10.8.10]

IS: 800-1984 (cl. 8.10 and 5.9] Recommedations:-

(a) Tacking Rivets:- A comp. member composed of two angles, channels, or tees back to back in contact or seperated by a small distance should be connected by riveting, bolting or welding, so that the slenderness ratio (le/rmin) of each member bet^n connections is not greater than 40 & nor - greater than 0.6 times most unfavourable slenderness ratio of the whole strut.

i.e. $\lambda \not> 40$, $\not> 0.6 \times \lambda_{unfavourable}$. } For comp. member - back to back with (tacking $\not>$ 600 mm)

For other types of "built up compreission member" say, where cover plates are used; pitch of tacking rivets should not exceed 32t or 300mm, whichever is less. (where t = Thk. of thinner outside plate] Where plates are exposed to weather [Due to weathering effect → (outside) pitch is decreased], pitch should not exceed 16t or 200 mm whichever is less.

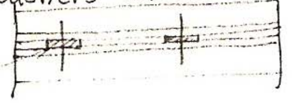
i.e. Pitch $\not>$ 32 t or 300 mm → Built up comp. member, No weathering
$\not>$ 16 t or 200 mm → subjected to weathering - outside

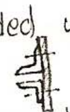
* Min. dia. of Rivets:-

Thk. of member	min. dia. of rivet
< 10 mm	16 mm
10 - 16 mm	20 mm
> 16 mm	22 mm

Bolt, Rivet, weld > should carry SF & BM if any

* solid packing or washers should be provided when members are seperated.





Seperated members.

② The ends of struts should be connected together with not less than 2 rivets or bolts or their equivalent in welding & there should not be less than 2 additional connections spaced equidistant in the length of strut.

* Min. 2 Rivets or bolts used at end connection one on line each gauge mark } **Where**
Legs of connected angles
or Flange of connected Tee > 125mm wide
or ~~to~~ web of channel connected > 150mm wide.

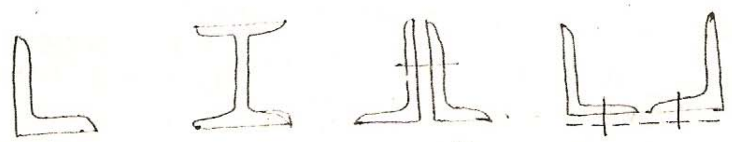
* <u>Typical cross-section of compression member:-</u>

Permissible comp. stress $\propto \frac{1}{\text{slenderness Ratio}} \propto \frac{r}{l_e}$

∴ section should be proportionated to have max. radius of gyration.

<u>GATE</u> * Circular pipe has best c/s in this regard & have highest radius of gyration in <u>all</u> directions. However due to difficulties in joining these sections are not preferred.

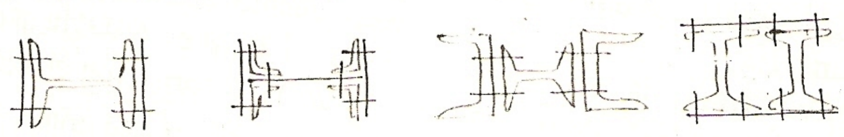
Various c/s used for compression member are:-

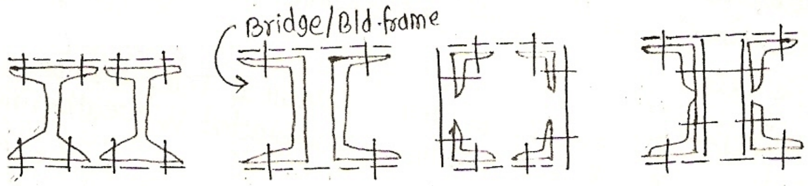


Single angle section
⇒ Simplest type
⇒ Used in trusses,
⇒ Bracing in PG
⇒ Built up colm.
Not economical as r is min. in minor principal axis & connectⁿ causes eccentricity.

I section & SC sections are most suitable. as diff. betⁿ 'r' @ two axes is smallest

---- ⇒ Lacing
—— cover plate.





Dotted line ⇒ ---- ⇒ Lacing
Thick line ⇒ —— ⇒ Cover plate.

Pro:] A column consisting of SC. 140 @ 33.3 kgf/m has an unsupported length of 4m. It is effectively held in position & restrained against rotation at one end & at the other end restrained against rotation but not held in position.
Determine the axial load this colᵐ can carry if the steel conforms to IS 226-1975.

Soln:- For SC: 140 @ 33.3 kg/m,
$a = 4.24\times10^3\ mm^2$
$r_x = 58.9\ mm$
$r_y = 32.1\ mm$
} From steel table.

f_y = Yield stress = 250 MPa – for steel conforming to IS 226-1975
∴ Slenderness ration $= \frac{le}{r_{min}}$.

From IS: 800-1984; Pg-41/cl. 5.2.2, Table 5.2;
effective length = le = 1.2L → case (d)
= 1.2×4
= 4.8 m.

$\therefore \lambda = \frac{4.8\times10^3}{32.1} = 149.53$.

∴ From Table 5.1 / Pg. 39, σ for λ = 149.53 & fy = 250 MPa.

σac =

λ	~~fy~~ σac
140	51
150	45
149.53	?

∴ By interpolation; $\sigma_{ac} = 51 - \frac{(51-45)}{(150-140)}(149.53-140)$

$\sigma_{ac} = 45.282$ MPa.

$\therefore \sigma_{ac} = \frac{P}{a} \Rightarrow P = a\cdot\sigma_{ac} = 4.24\times10^3\times45.282$

P = 192 kN

Pro 2] A single angle strut ISA 50×50×6 mm of a roof truss is 1.06 m long. It is connected by one rivet at each end. Determine the safe load this strut can carry.

Soln:- For ISA 50×50×6 mm;
$a = 5.68\times10^2\ mm^2$
~~Ixx = 12.9 cm4~~ Iuv = 5.3
Cxx = Cyy = 1.45 cm.
$\therefore r = \sqrt{I/A} = \sqrt{05.3\times10^4/5.68\times10^2} = 0.966\ cm = 9.66\ mm$

le = 1.06 m.

$\therefore \lambda = \frac{le}{r_{min}} = \frac{1.06\times10^3}{9.66} = 109.73$

From Table 5.1 / Pg. 39

λ	σac
100	80
110	72

$\therefore \sigma_{ac} = 80 - \frac{(80-72)}{(110-100)}(109.73-100)$

= 72.216 → see table,
Permissible stress = 0.8 × σac
for discontinuous single angle strut connected by single rivet at end.

$\therefore \sigma_{ac} = \frac{P}{A} \Rightarrow P = \sigma_{ac}\times A$

$= \frac{72.216\times5.68\times10^2\times0.8}{10^3}$

= ~~41.01 kN~~ 32.81 kN.

Pro: A double angle discontinuous strut consist of 2 ISA-6040, 6 mm thk. with longer legs back to back connected to opposite sides of a GP 10 mm thk. with two rivets. The length of strut betn c/c of intersection is 4m. Assuming tacking rivets have been provided along the length, determine the safe load carrying capacity of the section, if the yield stress for steel = 250 MPa.

Soln:- For 2 ISA 60×40×6 mm, from steel table

~~$a = 6.84\ cm^2 \Rightarrow 2a = 13.68\ cm^2$~~ $a = 5.65\ cm^2$

~~$I_{vv} = 9.1\ cm^4 \Rightarrow 2I_{vv} = 18.2\ cm^4$~~ $r_x = 1.88\ cm$

$c_y = 1\ cm$

$I_y =$ ~~$7\ cm^4$~~ $39.425\ cm^4$

~~$\therefore r_{min} = \sqrt{I/a} = 0.87$~~

$\therefore r_y = \sqrt{I_y/a} = \sqrt{7/5.65} =$

$L = 4m$

For two angle discontinuous strut with 2 rivets at each end,

$l_e = 0.85L$ & Per. stress in comp = σ_{ac}.

From steel table, for ISA 6040, 6 mm thk,

$a = 5.65\ cm^2$, $r_x = 1.88\ cm$, $c_y = 1.0\ cm$, $I_y = 7\ cm^4$

For strut, $r_x = 1.88\ cm$

$I_y = 2\times7 + 2\times5.65\,(1+0.5)^2 = 39.425\ cm^4$

$\therefore r_y = \sqrt{I_y/A} = \sqrt{\dfrac{39.425}{2\times5.65}} = 1.87\ cm$

$\therefore$ Min. radius of gyration = $r_{min} = r_y = 1.87\ cm$.

$l_e = 0.85L \longrightarrow$ from table.

$= 0.85\times4$

$= 3.4\ m$

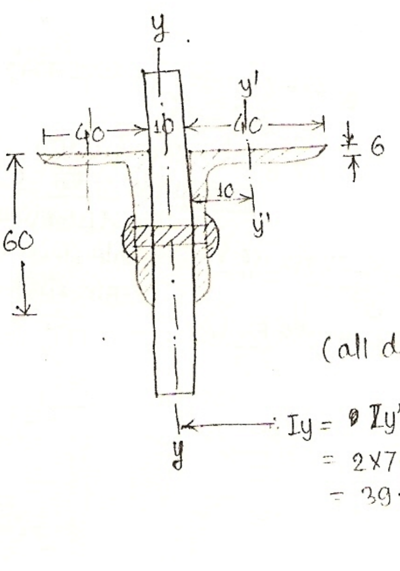
$\therefore$ Max. slenderness ratio $= \lambda = \dfrac{l_e}{r_{min}} = \dfrac{340}{1.87} = 181.8$

For strut used to carry load due to WL & EQ load, $l/r > 180$

$\therefore$ This strut should not be used for the same.

$\therefore$ From table 5.1, $\sigma_{ac} = 33 - (33-30)\times\dfrac{1.8}{10} = 32.46\ MPa$

$\therefore$ Safe load $= \dfrac{2\times32.46}{1000}\times5.65\times100 = \underline{36.67\ kN}$



(all dim. in mm)

$\therefore I_y = I_{y'} + A\cdot h^2$

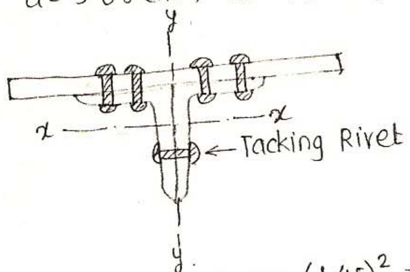
$= 2\times7 + 2\times5.65\times(1+0.5)^2$

$= 39.425\ cm^4$.

Pro: 4] A discontinuous strut 1.75 m long (effective) consist of two equal angles ISA 50x50x6 mm. It is connected to the same side of GP by two rivets on each angle at both ends. Calculate the load which this strut can carry if yield stress of steel is 250 MPa.

Sol^n:- I] Section Properties: from steel table: For ISA 50x50x6 mm,

$a = 5.68\ cm^2$, $r_x = 1.51\ cm$, $I_y = 12.9\ cm^4$, $c_y = 1.45\ cm$



$\therefore I_y = 2\times 12.9 + 2\times 5.68 \times (1.45)^2 = 49.68\ cm^4$.

$\therefore r_y = \sqrt{\frac{I_y}{a}} = \sqrt{\frac{49.68}{2\times 5.68}} = 2.09\ cm$

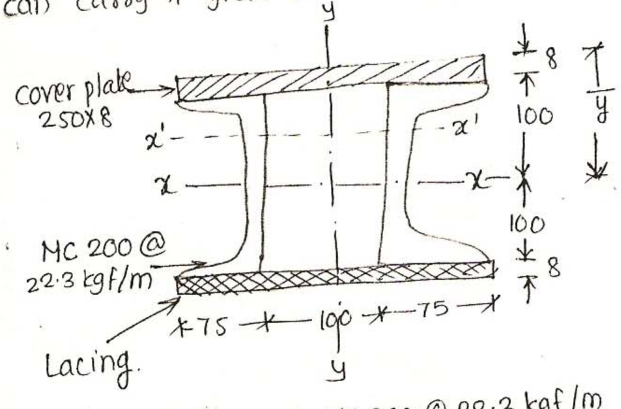
$\therefore r_{min} = r_y = 1.51\ cm$.

II] Slenderness Ratio $= \lambda = \frac{l_e}{r_{min}} = \frac{1.75\times 10^2}{1.51} = 115.89$

III] Permissible compressive stress $= \sigma_{ac} = 72 - (72-64)\times \frac{5.89}{10} = 67.29\ MPa$. — Table 5.1

IV] $\therefore$ Load carring capacity $= P = \sigma_{ac}\times a = \frac{2\times 67.29\times 568}{1000} = 76.44\ kN$

Pro: 5] The top chord of a bridge truss has an effective length of 4m & c/s as shown in fig. Determine the comp. load, this member can carry if yield stress of steel is 250 MPa.



① Section properties of MC 200 @ 22.3 kgf/m from steel table,

$a = 28.5\ cm^2$, $C_y = 2.18\ cm$, $I_x = 1830\ cm$, $I_y = 141\ cm^4$

② For strut ;

c/s area $= 2\times 28.5 + 25\times 0.8 = 77\ cm^2$

ΣM @ top fibre to calculate $\bar{y}$,

$\bar{y} = \frac{(2\times 28.5)(10+0.8) + 25\times 0.8\times 0.4}{2\times 28.5 + 25\times 0.8} = 8.098\ cm$.

$\therefore$ MI of section $= I_x = 2\times 1830 + 2\times 28.5(10.8 - 8.098)^2 + \frac{25\times 0.8^3}{12} + 25\times 0.8(8.098 - 0.4)^2$

$= 5262.39\ cm^4$

$I_y = 2\times 141 + 2\times 28.5(5+2.18)^2 + \frac{0.8\times 25^3}{12}$

$= 4262.15\ cm^4$.

as $I_x > I_y$; $r_x > r_y$

$\therefore r_{min} = r_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{4262.15}{2\times28.5 + 25\times0.8}} = 7.44$ cm.

③ ∴ Max. slenderness ratio = $\lambda_{max} = \frac{l}{r_{min}} = \frac{400}{7.44} = 53.76$.

④ Permissible comp. stress = $\sigma_{ac} = 132 - (132-122)\times\frac{3.76}{10} = 128.24$ MPa.

⑤ ∴ Safe load carring capacity of strut = $\sigma_{ac} \times a$

$= \frac{128.24(2\times28.5+25\times0.8)\times100}{1000}$

$= \underline{987.448 \text{ kN}}$

* Design of compression member:-

① Assume σ_{ac} < 80 MPa → Single angle - channel - I section; 110 MPa → Built up section.

② Find $A_{reqd} = \frac{\text{Axial Comp. load}}{\text{Per. comp. stress}} = \frac{P}{\sigma_{ac}}$

③ choose trial section having $A \simeq A_{reqd}$.

④ Determine λ_{max} & hence σ_{ac} act.

⑤ Safe load carring capacity = $\sigma_{ac\,cal} \times A_{pro} \geq P$

∴ O.K. otherwise Revise the section.

⑥ check for slenderness ratio according to IS: 800-1984, Table 3.7.1/Pg 30

Pro 1] Design a column section to carry axial load of 410 kN. The col^m is 4.2 m long & is effectively held in position at both ends but restrained against rotation at one end only. Yield stress of steel = 250 MPa.

Sol^n:- ① Assume $\sigma_{ac} = 80$ MPa.

② $A_{reqd} = \frac{P}{\sigma_{ac}} = \frac{410\times10^3}{80} = 5125 \text{ mm}^2$

③ from steel table, try SC-160 @ 41.9 kgf/m

Cross area = a = 5340 mm²

$r_{min} = 36.1$ mm.

④. Max. slenderness ratio = $\lambda_{max} = \frac{l_e}{r_{min}} = \frac{0.8\times4.2\times10^3}{36.1} = 93.07 < 180$ ↑ From IS: 800/ Pg. 30 /cl. 3.7.1

⑤ ∴ $\sigma_{ac} = 90 - (90-80)\times\frac{3.07}{10} = 86.93$ MPa

[From IS: 800 / Table 5.1]

⑥ ∴ Safe load carring capacity = $\frac{86.93\times5340}{1000} = 464 \text{ kN} > 410 \text{ kN}$

∴ O.K.

| Use SC 160 @ 41.9 kgf/m |

Pro: 2] Design a suitable angle strut for a roof truss carrying a comp. load of 97 kN. The length of strut bet^n c/c intersection is 910 mm. Also design a) Riveted b) welded connections.

Soln:- ① Assuming for strut that both ends are connected by more than one rivet & yield stress of steel = 250 MPa.

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$\therefore l_e = 0.85L = 0.85 \times 2100 = 1785$ mm.

② Assume $\sigma_{ac} = 80$ MPa

$\therefore A_{reqd} = \frac{P}{\sigma_{ac}} = \frac{97 \times 10^3}{80} = 1212$ cm^2

③ $\therefore$ Try for single angle ISA 80X80X8 mm

$a = 12.21$ cm^2, $r_{min} = 1.55$ cm

④ $\therefore$ Max. slenderness ratio $= \lambda_{max} = \frac{l}{r_{min}} = \frac{1785}{155} = 115.16 < 180$ $\therefore$ O.K.

⑤ $\therefore$ From Table 5.1 / Pg 39, $\sigma_{ac} = 67.87$ MPa.

⑥ $\therefore$ Load carrying capacity $= \sigma_{ac} \times a = \frac{67.87 \times 97 \times 10^3 1221}{1000} = 82.87$ kN < 97 kN

$\therefore$ Unsafe.

⑦ Revise the section.

Let $\sigma_{ac} = 68$ MPa $\rightarrow$ from step ⑤

$\therefore A_{reqd} = \frac{97 \times 10^3}{68} = 1426$ mm^2

⑧ Try for single angle ISA 80x80x10 mm,

$a = 1505$ mm^2, $r_{min} = 15.5$ mm

⑨ $\therefore \lambda_{max} = \frac{l}{r_{min}} = \frac{1785}{15.5} = 115.16 < 180$ $\therefore$ O.K.

⑩ $\therefore$ From Table 5.1 / Pg.39, $\sigma_{ac} = 67.87$ MPa.

⑪ $\therefore$ Safe load carrying capacity $= \frac{67.87 \times 1505}{1000} = 102$ kN > 97 kN $\therefore$ O.K.

a) Design of Riveted end connection:

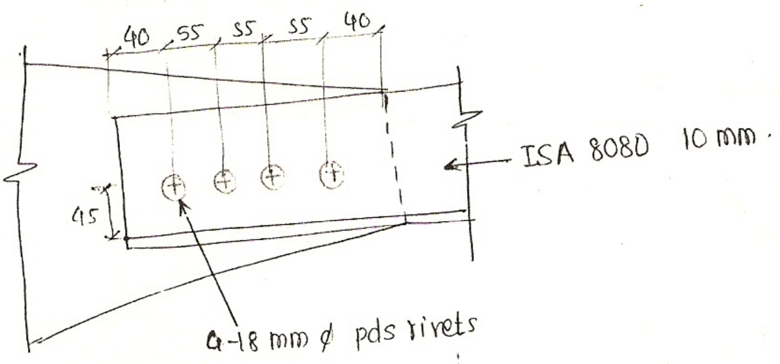
① $\therefore$ Strength of 18 mm dia. shop rivets <
- In single shear $= 100 \times \frac{\pi}{4} \times 19.5^2 = 29.86$ kN
- In bearing 10 mm thk. leg $= 300 \times 19.5 \times 10 = 58.5$ kN.

② $\therefore$ Rivet value $= 29.86$ kN.

③ No. of Rivets reqd $= \frac{97}{29.86} = 3.24 \approx 4$ No's.

④ Pitch $= 2.5 \times 19.5 = 48.75 \approx 55$ mm.

⑤ Edge dist $= 2 \times 19.5 \approx 40$ mm.



ⓑ Design of welded end connection:-

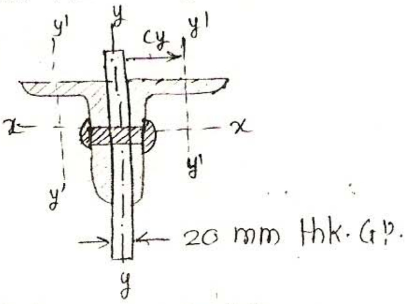
① Max. size of fillet weld $= \frac{3}{4} \times 8 = 6$ mm.

② Length of weld reqd $= \frac{97000}{0.7 \times 6 \times 108} = 213.8 \approx 215$ mm

See problem on Tension member & provide length of weld such that C.G. of weld & C.G. of load coinsides. So that no eccentricity will exists.

Pro 3] A strut in a roof truss carries an axial comp. load of 180 kN. Determine a Design a suitable double angle section for the compression member. The length of strut betn c/c of intersection is 2.3 m & yield stress of steel is 250 MPa.

Soln:- Assume that double angles section is to be connected on both side of 20 mm thk. GP by more than one rivet at each end.



$\therefore l_e = 0.85l = 0.85 \times 2.3 = 1.955 m$

① Assume $\sigma_{ac} = 80$ MPa

$\therefore A_{reqd} = \frac{180 \times 10^3}{80} = 2250 \; mm^2$

② Try 2 ISA 75 50 10 mm,

For each angle, $a = 11.52 \; cm^2$, $r_x = 2.33$ cm, $I_y = 21.8 \; cm^4$, $c_y = 1.36$ cm.

③ For strut, $a = 2 \times 11.52 = 23.04 \; cm^2$

$I_y = 2 \times 21.8 + 2 \times 11.52 \, (1.36 + 1.0)^2 = 171.9 \; cm^4$

$\therefore r_y = \sqrt{\frac{I_y}{a}} = \sqrt{\frac{171.9}{23.04}} = 2.73$ cm

$\therefore r_{min} = 2.33$ cm $= r_x$

④ $\lambda_{max} = \frac{l}{r} = \frac{1955}{23.3} = 83.9 < 180 \quad \therefore$ O.K.

⑤ From Table 5.1, $\sigma_{ac} = 96.71$ MPa

⑥ $\therefore$ Safe load $= \frac{96.71}{1000} \times 23.04 \times 100 = 222.8$ kN >> 180 kN. $\therefore$ O.K.

* End connections:-

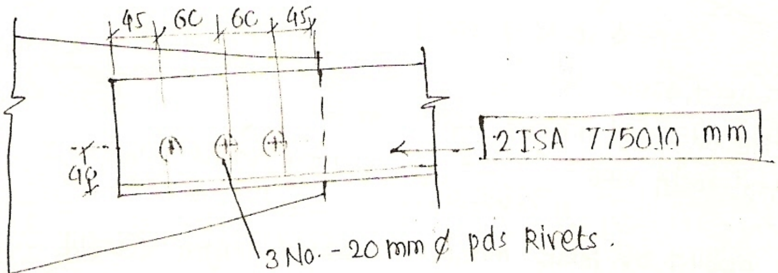
① Rivet value for 20mm dia. pds rivets < Double shear $= 2 \times 100 \times \frac{\pi}{4} \times 21.5^2 = 72.6$ kN ; Bearing $= 300 \times 20 \times 21.5 = 129$ kN

$\therefore$ Rivet value = 72.6 kN.

② No. of Rivets reqd $= \frac{180}{72.6} = 2.4 \simeq 3$ No's.

③ Pitch = 60 mm (2.5d)

④ Edge dist = 45 mm (2d)



Notes by-

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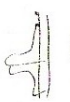
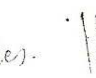
$\frac{3A1}{3A1+A2}$


$\frac{SA1}{SA1+A2}$


$\frac{3A1}{A1+A2}$
$A1 = (b-d-t/2)t$
$A2 = (b-t/2)t$


$\frac{SA}{SA1}$
$A1 = (b-d-t/2)t$
$A2 = (b-t/2)t$


Ag - Holes.


Anet = $(b - nd \frac{t}{2})t$

Compression Member

F — 0.65, 0.8, S.S. — 1

Effective length:-

① Both end fixed : ~~Le = 0.8L~~ Le = 0.65L
② One end fixed :- Le = 0.8L
③ S.S. Le = L

---

pacity of col^m :-

Find λmax & find δac from IS code

∴ $\lambda max = \frac{le}{rmin}$ → 0.65L → Fixed end
0.8L → one end fixed
1L → S.S.

∴ P = $\delta ac \times Ag$

| $\delta ac = 80 MPa$
 $\delta at = 150 MPa$ | $\delta ac = 110 MPa$ ⇒ Lacing |

Lacing ⇒ Eccentric
Battening ⇒ axial

esign of Lacing:-

Given :- P = 1200 kN.
L = 8m

Let Areqd = $\frac{P}{\delta ac} = \frac{1200}{110} = 10.9 \times 10^3\ mm^2$

∴ Provide 2ISLC 350 having.
$A_g = 99.08\ cm^2$, $r_{min} = r_x = 13.72$ cm
cy = 60 mm)

$\lambda max = \frac{le}{rmin}$
$= \frac{0.85 \times L}{137.2} = 49.56$

Find δac > δac assumed
∴ O.K.

Let $\boxed{S = 200 mm}$

∴ ~~Length of lacing bar~~ = 2[
Assume single lacing system inclined at 45° with axis of col^m.

∴ Length of lacing bar = 2(S+2(y)
= 2(200+2×60)
= 640 mm.

Assume thk. of lacing bar = 12 mm.
Assume width of lacing bar = 60 mm.

*. Try 60×12 mm flat

check :- ① Transverse shear = 0.025 P
= 30 kN.

② $F = \frac{V}{2 sin 45} = \frac{30}{2 sin 45} = 21.21$ kN.

③ ∴ ~~Tensile stress~~ = $\frac{21.21}{~~(60 \times 12)~~}$

∴ Area of plate = Anet = (b-d)×t
assume 20 mm pd's rivet
∴ d = 21.5 mm

∴ ③ Tensile stress = $\frac{21.21}{(60-21.5) \times 12}$ = 45.9 > 150 ∴ O.K.

④ comp. stress = $\frac{21.21}{60 \times 12}$ = 29 > 110 ∴ O.K.

End connection:-

Rivet value < $\frac{\pi}{4} \times d^2 \times \tau vf$ = 36.3 kN ✓
$\delta tf \times d \times t$ = ~~36~~ 77.4 kN.

No. of Rivet reqd = $\frac{F}{R}$ = 1 No.

*. Steps in Design

① Areqd = $\frac{P}{\delta ac}$ $\boxed{\delta ac = 110\ MPa}$
② choose section.
③ check for $\lambda max = \frac{le}{rmin}$ → 0.65 - Fixed, 0.8 → one end, 1.0 → S.S.
④ Find δac ≯ 110 MPa. ∴ O.K.
⑤ Assume S = 200 mm. *
⑥ ~~Le~~ θ = 45° (single lacing) → Assume.
⑦ Length of lacing bar reqd = 2(S+2cy).
⑧ Assume thk. of lacing = 12 mm
Width of lacing = 60 mm.
⑨ Let V ~~F~~ = 0.025P
⑩ ~~V~~ F = $\frac{V}{2 sin \theta}$
⑪ Tensile stress = $\frac{F}{Anet}$ ≯ 150 MPa ∴ O.K. Fixed.

Anet = (b-d)×t   (b = 60, t = 12, d = 21.5)

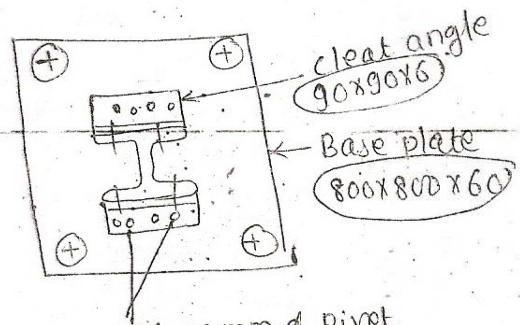
⑫ Comp. stress = $\frac{F}{Ag}$ ≯ 110 MPa or calculated.

Ag = b×t

⑬ ∴ Provide lacing bar of size L×60×12 mm
⑭ End connection:-
Rivet value < ~~Le~~ In shearing = $\tau vf \cdot \frac{\pi}{4} d^2$
In bearing = $\delta tf \times d \times t$
⑮ No. of Rivet reqd = $\frac{F}{R}$ = 1

$f_1 + \frac{2}{3}(f - f_1)$

Slab Base:-



Area of plate reqd = $\frac{P}{\sigma_{bc} = 4000}$

∴ Length of plate = $\sqrt{A}$

Thk = 60 mm

cleat angle = 2 ISA 90x90x6

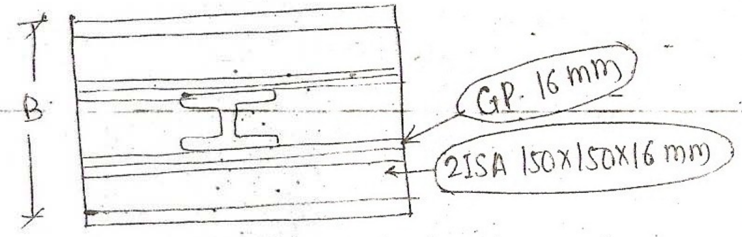
4 - ø - 20 mm pds rivet

concrete slab :-

Area of Concrete base = $\frac{1.1 \times P}{\sigma_{ac} = 100}$

Assume 45° dispersion angle.

Gusseted Base



Area of plate reqd = $\frac{P}{\sigma_{bc} = 4000}$

Find width = B

Length = $\frac{A}{B}$

To find thk. take section at GP & at angle connection

t = 20mm

Fastening :-

Rivet Value < single / double.

BEAM

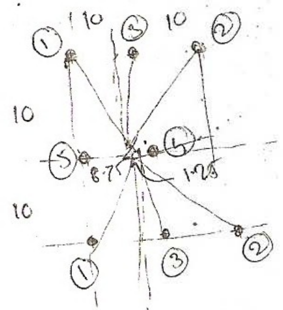
Flexural Member

Find $Z_{reqd} = \frac{M}{\sigma_{bc}} \rightarrow 150$

Force due to direct load = $F_a = \frac{P}{n}$

$= \frac{60}{8} = 7.5 kN$

Force due to mmt = $F_m = \frac{M \cdot r}{\Sigma r^2} = 25.27$



$r_1 = 13.288 \times 2$

$r_2 = 15.05 \times 2$

$r_3 = 10.078 \times 2$

$r_4 = 1.25 \times 1$

$r_5 = 8.75$

$\Sigma r^2 = 1116.689$

$y = \frac{3 \times 10 + 2 \times 20}{8}$

$= 8.75$ mm

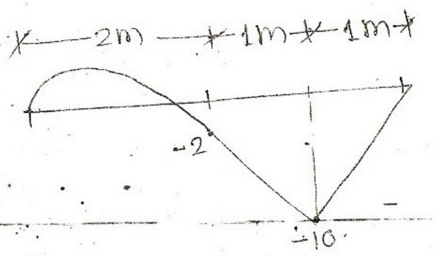
$\frac{60 \times [20 + (20 - 8.75)]}{1116}$

$F_r = \sqrt{F_a^2 + F_m^2 + 2 F_a F_m \cos\theta}$

$\theta = \tan^{-1}\left(\frac{10}{11.25}\right)$

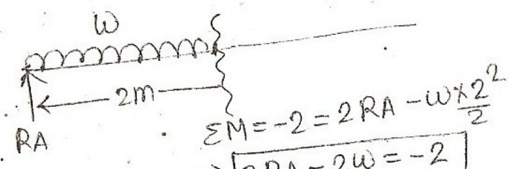
$= 41.634$

∴ $F_r = 31.275$ kN



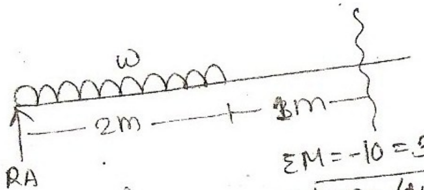
raw BMD

td 1:-



$\Sigma M = -2 = 2RA - w \times \frac{2^2}{2}$

$\Rightarrow \boxed{2RA - 2w = -2}$

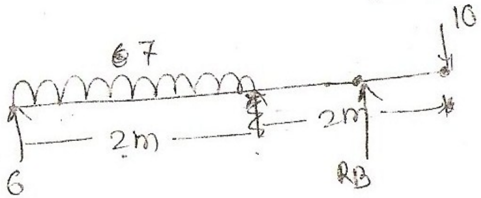


$\Sigma M = -10 = 3RA - w(2) \times 2$

$\Rightarrow \boxed{3RA - 4w = -10}$

$\therefore RA = 6\ kN$

$w = 7\ kN/m.$



second Mtd:-

$M = ax^2 + bx + c$

$V = 2ax + b$

$-w = \frac{dV}{dx} = 2a$

$\therefore$ at $x = 0,\ M = 0, \quad x = 2,\ M = -2$

$\therefore 0 = 0 + 0 + c \Rightarrow c = 0$

$-2 = 4a + 2b$ — (1)

at $x = 2\ V = -8$

$\therefore -8 = 4a + b$ — (2)

$\therefore a = -3.5$

$b = 6.$

~~$M = 6x^2$~~ ~~$M = 3x$~~

$\boxed{M = -3.5x^2 + 6x}$

$\boxed{V = -7x + 6}$

$\boxed{w = +7\ kN}$

Solve :-

~~$Hz = 2\pi$~~

$\therefore \omega = 2\pi\ Hz$

$= \frac{2\pi N}{60}$

$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$

$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$

$P = T \times \frac{2\pi N}{60}$

$\frac{\pi^2 EI}{L^2}$

$\frac{fy \cdot A}{1 + a\lambda^2}$

Eulers formula

$P_{cr} = \frac{\pi^2 EI}{le^2}$

$f_{cr} = \frac{\pi^2 E}{\lambda^2}$

$\lambda \geq \sqrt{\frac{\pi^2 E}{f_{cr}}}$

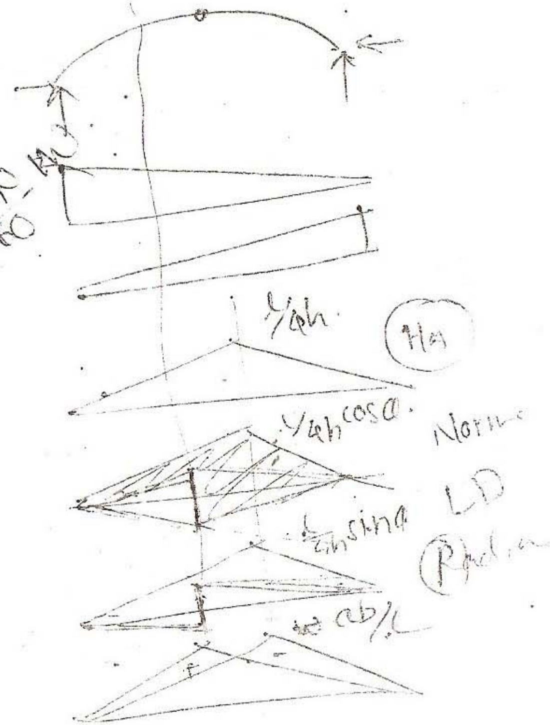
PR = Rankines

$= \frac{P\ fy \cdot A}{1 + a\lambda^2}$

$r = \sqrt{I/A}$

$I = r^2 A$

$le = \frac{l}{r}$



Rivet:

~~① strength of joint per pitch:~~

~~smaller of ①…~~

* Rivet value - In shearing - $\tau_{vf} \cdot \frac{\pi}{4} \cdot d^2$
  - In Bearing - $\sigma_{pf} \times d \times t$

* **Riveted Joint (axially loaded member)**

① Dia of Rivet = $6\sqrt{\text{Thk of plate (mm)}}$

② No. of Rivet reqd = $\frac{\text{Load}}{\text{Rivet value}}$

③ Pitch = 3D

④ Edge Dist = 2D

	Pds	Acid
τ_{vf}	100	80
σ_{pf}	300	250

* **Riveted Joint (Eccentric): Bracket I:**

① F_a = Force due to direct load = $\frac{P}{n}$

② F_m = Force due to moment = $\frac{M \cdot r}{\Sigma r^2}$

③ F_r = Resultant = $\sqrt{F_a^2 + F_m^2 + 2F_aF_m\cos\theta}$

θ = Angle bet^n F_a & F_m

No tension condition,

$$\frac{\tau_{vf\,cal}}{\tau_{vf}} + \frac{\sigma_{tf\,cal}}{\sigma_{tf}} \not> 1.4$$

Design steps:-

① Assume Rivet dia = $6\sqrt{\text{thk of plate}}$

② Rivet value < Shear = $\frac{\pi}{4} d^2 \times \tau_{vf}$; Bearing = $\sigma_{pf} \cdot d \cdot t$

③ No. of Rivets reqd = $\frac{P}{R}$

Increase by 3 Times

or $n = \sqrt{\frac{6M}{m \cdot p \cdot R}}$ — p = pitch, m = No. of rows, R = Rivet value

④ check; $\frac{\tau_{vf\,cal}}{\tau_{vf}} + \frac{\sigma_{tf\,cal}}{\sigma_{tf}} \not> 1.4$

ⓐ $\sigma_{tf\,cal} = \frac{6M}{m \cdot p \cdot n^2 \cdot A_r}$

ⓑ $\tau_{vf\,cal} = \frac{\text{Direct shear load on each Rivet}}{\text{Area of Rivet}}$

* **Butt Joint Eccentric:-**

① Shear stress at weld = $P_s = \frac{P}{d \cdot t}$

② Tensile/comp stress due to bending =

$$P_b = \frac{6M}{td^2}$$

③ P_e = Equivalent stress = $\sqrt{P_b^2 + 3P_s^2}$

P_e permissible = $0.9 f_y$ = 225 MPa

④ length of weld = $\sqrt{\frac{6M}{t \cdot P_b}}$

P_b = 165 MPa

Fillet Weld : Bracket I : Eccentric

① Vertical shear stress = $P_s = \frac{W}{\ell \times t}$

② Torsional stress = $P_b = \frac{M \cdot r}{I_p}$, $M = W \times e$

$I_p = I_x + I_y$

③ Resultant stress

$$P_r = \sqrt{P_s^2 + P_b^2 + 2P_s \cdot P_b\cos\theta}$$

$P_r \not> 108$ MPa

Fillet weld: Bracket II : Eccentric

① Vertical stress = $P_s = \frac{W}{2 \times \ell t}$

② Bending stress = $P_b = \frac{6 \times M}{2t\ell}$

③ Resultant stress = $P_r = \sqrt{P_s^2 + P_b^2}$ $\not> 108$ MPa.

size of fillet weld = 6 mm.

strength of fillet weld = $P_q \times \ell \times 0.707\,S$

$= 108 \times 0.707 \times S \times \ell$

$A_2 = (b - t/2)\,t$
$= (75-4)\times 8$
$= 568\ mm^2$

$\therefore$ ~~Anet~~ $k = \frac{3A_1}{3A_1 + A_2}$
$= 0.685$

$\therefore A_{net} = A_1 + A_2 k$
$= 801.16\ mm^2$

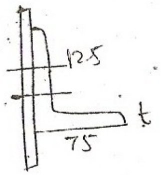
$\therefore$ Area of 4 angles $= 3204.6\ mm^2$
$\therefore P = \delta_{at} \times A_{net}$
$= 150 \times 3204.6 \times 10^{-3}$
$= 480.7\ kN$

② Tacking is done along ~~A & C~~ B & D
$\therefore A_1 = (b - d - t/2)\,t$
$= 412\ mm^2$
$A_2 = 568\ mm^2$
k ~~Anet~~ $= \frac{5A_1}{5A_1 + A_2}$
$= 0.789$

$\therefore A_{net} = A_1 + A_2 k$
$= 857.23\ mm^2$
$\therefore P = 857.23 \times 4 \times 150 \times 10^{-3}$
$= 514.34\ kN$

③ If A & C are tacked.
They acts as double angle section connected back to back:
$\therefore A_{net} = A_g -$ deduction for hole
$=$ ~~75~~ ~~4×~~ $1138 -$ ~~1.9~~ 19.5×8
$= 982\ mm^2$
$\therefore P = 982 \times 150 \times 10^{-3} \times 4$
$= 589.2\ kN$

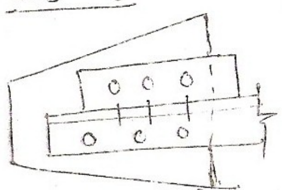
④ Tacking is done to all ~~rivet~~ angles, same as above.



$P = 160\ kN$
$d = 18 + 1.5 = 19.5\ mm$
$t = ?$

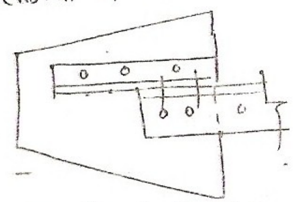
Design :- ① $A_{net\,reqd} = \frac{P}{\delta_{at}}$ ⇒ Try for section.
② Find $A_{net\,pro} > A_{net\,reqd}$ ∴ OK
③ check of $\lambda := \frac{l_e}{r_{min}} \not> 350$ ∴ O.K.

Lug angle :-



Transfer load.
to save length of G.P.

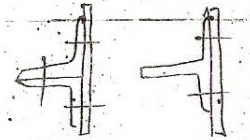
Tension splice



Length of Tension member is less.

① Area of Plate : $A_{net} = (b - nd$ ~~+ t/2~~$) \times t$
If joints are staggered,
add $\left(\frac{s^2 t}{4g}\right)$.

② ~~Single~~ Double angles on same side of GP (back to back)

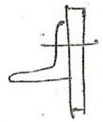


$A_1 = A_{net}$ of connected leg
$= (b - d - t/2)\,t$
$A_2 = A_{gross}$ of connected leg
$= (b - \frac{t}{2}) \times t$

~~$A_{net} = A_1$~~ $K = \frac{5A_1}{5A_1 + A_2}$

$A_{net} = A_1 + A_2 K$

③ Single angle ~~on~~ connected to GP



$A_{net} = A_1 + A_2 K$
$A_1 = (b - d - t/2)\,t$
$A_2 = (b - t/2)\,t$
~~Ano~~ $K = \frac{3A_1}{3A_1 + A_2}$

$A_{net} = A_1 + A_2 K$.

④ Double angle on either side of GP.
$A_{net} = A_g -$ deduct^n for hole.