3. COMPRESSION MEMBER

STRENGTH OF AN AXIALLY LOADED COMPRESSION MEMBER

- The maximum axial compressive load P

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

where, P = axial compressive load (N)

σ_{ac} = permissible stress in axial compression (MPa)

A = gross-sectional area of the member (mm^2)

- IS : 800-1984 uses the Merchant Rankine formula for σ_{ac} which is given as

$$\sigma_{ac} = 0.6 \times \frac{f_{cc} \times f_y}{\left[f_{cc}^n + f_y^n\right]^{1/n}}$$

where, f_{cc} = elastic critical stress in compression $= \frac{\pi^2 \times E}{\lambda^2}$

λ = slenderness ratio $= \frac{l}{r}$

l = effective length of the compression member.

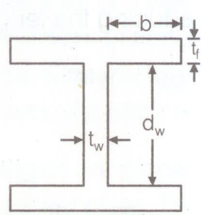
r = appropriate radius of gyration of the member (minimum value)

E = modulus of elasticity of steel = 2×10^5 MPa

n = a factor assumed as 1.4

Remember

- According to **IS : 800-1984**, the direct stress in compression on the gross cross-sectional area of axially loaded compression member shall not exceed $0.6f_y$, nor the permissible σ_{ac} value calculated using the above formula.
- The critical stress at which the plate buckles is inversely propational to $(b/t)^2$.
- To prevent the buckling of flange plate and web plate.



$$\frac{b}{t_f} \not> 16, \quad \frac{d_w}{t_w} \not> 50$$

- Maximum Slenderness Ratio (Clause 3.7.1 IS:800-1984)

Sl. No.	Type of member	Max. slenderness ratio
1.	A member carrying compressive loads resulting from dead load and superimposed loads	180
2.	A member subjected to compressive loads resulting from wind/earthquake forces provided the deformation of such members does not adversely affect the stress in any part of the structure	250
3.	A member normally carrying tension but subjected to reversal of stress due to wind or earthquake forces	350

EFFECTIVE LENGTH

Table: (Effective length of compression members of constant dimensions (Clause 5.2.2 IS : 800-1984)

Sl. No.	*Degree of end restraint of compression member*	*Recommended value of effective Length*	*Symbol*
1.	Effectively held in position and restrained against rotation at both ends	0.65L	
2.	Effectively held in position at both ends restrained against rotation at one end	0.80L	
3.	Effectively held in position at both ends, but not restrained against rotation	1.00L	
4.	Effectively held in position and restrained against		

	rotation at one end, and at the other end restrained against rotation but not held in position.	1.20L	
5.	Effectively held in position and restrained against rotation at one end, and at the other end partially restrained against rotation but not held in position	1.50L	
6.	Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position	2.00L	
7.	Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end	2.00L	

NOTE: For battened columns, the effective length shall be increased by 10%

ANGLE STRUTS

- The slenderness ratio ($\lambda = l/r$) should not exceed the values given in Table).

Table: Angle Struts (Clauses 5.5, IS : 800 -1984)

Sl. No.	Type	End Connections	Effective length	Allowable stress	Slenderness Ratio
1.	Single angle discontinuous	(i) One rivet or bolt at each end	l = L	$0.8\sigma_{ac}$	180
		(ii) Two or more rivets or bolts or welding at each end	l = 0.85L	σ_{ac}	-
2.	Double angle, tacked, discontinuous	(i) Connected on same side of gusset plate (a) One rivet or bolt at each end	l = L	$0.8\sigma_{ac}$	$\frac{l}{r} \not> 180$
		(b) Two or more rivets, bolts or welding at each end	l = 0.85L	σ_{ac}	-
		(ii) Connected on both Sides of gusset plate by two or more rivets, bolts or welding	l = 0.7 to 0.85L depending on rigidity of joint	σ_{ac}	-
3.	Single or double angle continuous	One or more rivet, bolt or welding	l = 0.7L to 1.0L depending on end rigidity	σ_{ac}	-

BUILT-UP COMPRESSION MEMBER

Tacking Rivets

- The slenderness ratio of each member between the connections should not be greater than 40 nor greater than 0.6 times the most unfavorable slenderness ratio of the whole strut. In no case should the spacing of tacking rivets in a line exceed 600 mm for such members, i.e. two angles, channels or tees placed back-to-back.
- For other types of built-up compression members, say where cover-plates are used, the pitch of tacking rivets should not exceed 32 t or 300 mm, whichever is less, where *t* is the thickness of the thinner outside plate. When plates are exposed to the weather, the pitch should not exceed 16 *t* or 200 mm whichever is less.
- The diameter of the connecting rivets should not be less than the minimum diameter given below.

Thickness of member	Minimum diameter of rivets
Up to 10 mm	16 mm
Over 10 mm to 16 mm	20 mm
Over 10 mm	22 mm

DESIGN OF COMPRESSION MEMBERS

The following steps are followed for designing an axially loaded compression member:

(i) Assume some value of permissible compressive stress σ_{ac} and calculate the approximate gross sectional area A required

$$A_{approx} = \frac{\text{Axial compressive load}}{\text{Assumed permissible stress}}$$

For single-angle-channel-or I-section (low loads) 80 MPa and for built-up sections (heavy loads) 110 MPa may be assumed initially as permissible compressive stress.

(ii) Choose a trial section having area $\simeq A_{approx}$.

(iii) Determine the actual permissible stress corresponding to maximum slenderness ratio l/r of the trial section.

(iv) Calculate the safe load to be carried by trial section by multiplying, the actual permissible stress by the area of the trial section.
If the safe load is equal to or slightly more than the actual load, the trial section is suitable for selection. Otherwise the above steps should be repeated.

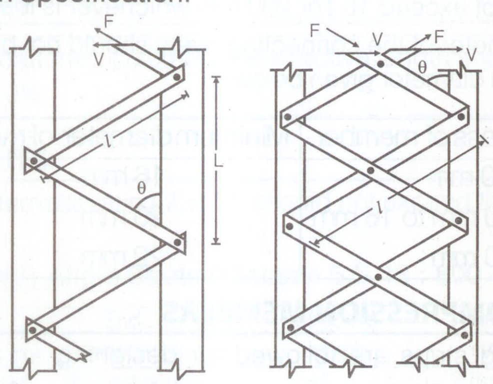
(v) Check the slenderness ratio.

LACINGS

(a) General requirements:

1. Radius of gyration about the axis $\perp$ to the plane of lacing $\nless$ radius of gyration about the axis in the plane of lacing
2. The lacing system should not be varied throughout the length of the strut as far as practicable.
3. The single-laced systems on opposite sides of the main components should preferably be in the same direction so that one be the shadow of the other.

(b) Design Specification:



(a) Single lacing (b) Double lacing

1. The angle of inclination of the lacing with the longitudinal axis of the column should be between 40° to 70°.
2. The slenderness ratio l_e/r of the lacing bars should not exceed 145. The effective length l_e of the lacing bars should be taken as follows:

Type of lacing	Effective length l_e
Single lacing, riveted at ends	Length between inner end rivets on lacing bar ($= l$, as shown in Fig. 17)
Double lacing, riveted at ends and at intersection	0.7 times length between inner end rivets on lacing bars ($= 0.7 \times l$)
Welded lacing	0.7 times distance between inner ends of effective lengths of welds at ends ($0.7 \times l$)

Lacing is generally preferred in case of eccentric loads. Battening is normally used for axially loaded columns and where the components are not far apart.

3. For local Buckling Criteria

$$\frac{L}{r^c_{min}} \ngtr 50$$
$$\ngtr 0.7\,\lambda_{\text{whole section}}$$

where, L = distance between the centres of connections of the lattice bars to each component as shown in fig.

r^c_{min} = minimum radius of gyration of the components of compression member

4. Minimum width of lacing bars in riveted construction should be as follows:

Nominal rivet diameter (mm)	22	20	18	16
Width of lacing bars (mm)	65	60	55	50

5. Minimum thickness of lacing bars:

$t \nless l/40$ for single lacing

$\nless l/60$ for double lacing riveted or welded at intersection

where, l = length between inner end rivets as shown in fig.

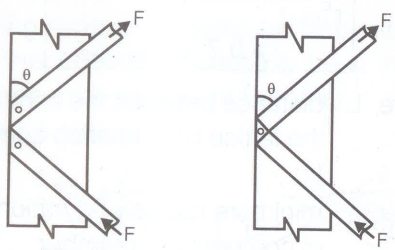
6. The lacing of compression members should be designed to resist a transverse shear, V = 2.5% of axial force in the member.

- For single lacing system on two parallel faces, the force (compressive or tensile) in each bar, $\boxed{F = \dfrac{V}{2\sin\theta}}$
- For double lacing system on two parallel planes, the force (compressive or tensile) in each bar, $\boxed{F = \dfrac{V}{4\sin\theta}}$
- If the flat lacing bars of width b and thickness t have rivets of diameter d then,

$$\text{Compressive stress in each bar} = \frac{\text{force}}{\text{gross area}} = \frac{F}{b \times t} \not> \sigma_{ac}$$

- Tensile stress in each bar $= \dfrac{\text{force}}{\text{net area}} = \dfrac{F}{(b-d)\times t} \not> \sigma_{at}$

7. End Connections:
   - ***Riveted connection:*** Riveted connections may be made in two ways as shown in Fig. (a) and (b).



(a) (b)

For case (a),

$$\boxed{\text{Number of rivets required} = \frac{F}{\text{Rivet value}}}$$

Force case (b),

- Number of rivets required $= \dfrac{2F\cos\theta}{\text{Rivet value}}$

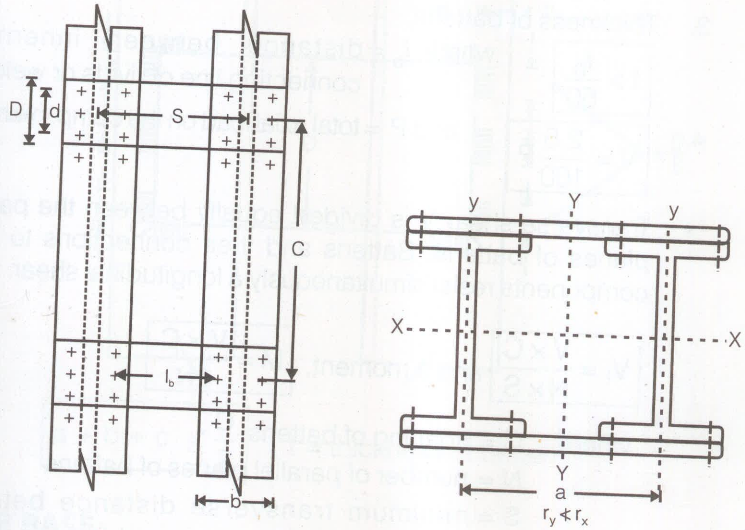
- **Welded connections**

  Lap joint : Overlap $\not<$(1/4) times thickness of bar or member, whichever is less.

  Butt joint : Full penetration butt weld or fillet weld on each side. Lacing bar should be placed opposite to flange or stiffening member of main member.

BATTENS

(a) General Requirements:



1. $\boxed{r_y \not< r_x}$

2. The number of battens should be such that the member is divided into not less than three parts longitudinally.

(b) Design Specifications:

1. Spacing of battens C, from centre to centre of end fastening should be such that the slenderness ratio of the lesser main component,

$\dfrac{C}{r^c_{mm}} \not> 50$, or 0.7 times the slenderness ratio of the compression member as a whole about $x - x$ axis (parallel to battens), which is less

where C = spacing of battens as shown in fig.

r^c_{min} = minimum radius of gyration of components.

2. $\boxed{d > \left(\dfrac{3}{4}\right) a}$ for intermediate battens,

d > a for end battens

and d > 2 × b for any batten.

where d = effective depth of batten,

a = centroid distance of members,

b = width of member in the plane of batten

3. Thickness of battens,

$$t > \frac{l_b}{50}$$

where, l_b = distance between innermost connecting line of rivets or welds.

4. $$V = \frac{2.5}{100} P$$

and P = total axial load on the comp. member.

- Transverse shear V is divided equally between the parallel planes of battens. Battens and their connections to main components resist simultaneously a longitudinal shear.

$$V_1 = \frac{V \times C}{N \times S}$$ and a moment, $$M = \frac{V \times C}{2N}$$

where, C = spacing of battens

N = number of parallel planes of battens

S = minimum transverse distance between centroids of rivet group or welding.

- Check for longitudinal shear stress,

$$\frac{V_1}{D \times t} \ngtr \tau_{va}$$

where, t_{va} = permissible average shear stress = 100 MPa for steel of IS : 226-1975

D = overall depth of battens,

t = thickness of battens.

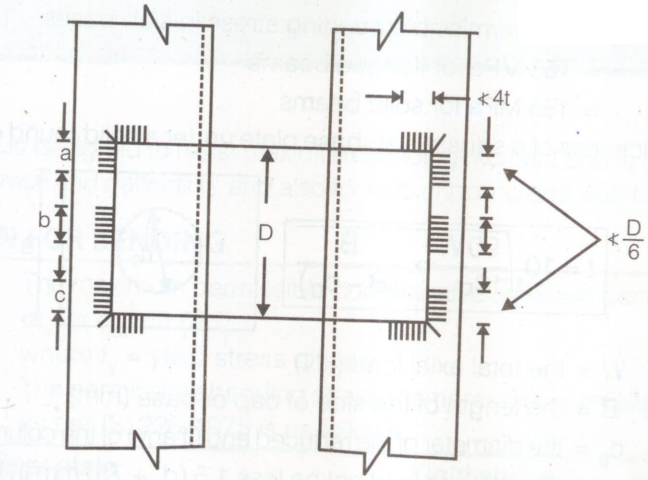
- Check for bending stress,

$$\frac{M}{Z} = \frac{M}{\frac{1}{6} D \times t^2} \ngtr \sigma_{bc\,or\,bt}$$

where, $\sigma_{bc} \sigma_{bt}$ = permissible bending compressive or tensile) stress = 165 MPa for steel of IS : 226-1975

5. End connections:

- Design the end connections to resist the longitudinal shear force V_1 and the moment M as calculated in steep 4 above.
- For welded connections Lap ≮ 4t Where t is thickness of plate
- Total length of weld at end of edge of batten ≮ D/2
- Length of weld at each edge of batten ≮ 1/3 total length of weld required
- Return weld along transverse axis of column ≯ 4t where, t and D are the thickness and overall depth of the battens respectively.

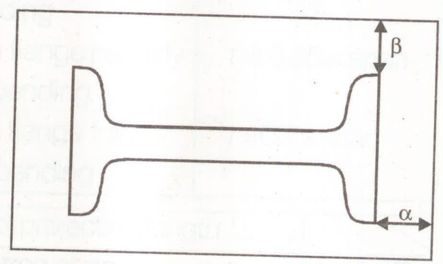


$$a + b + c \nless \frac{D}{2}$$ t = thickness of batten

SLAB BASE

- Sufficient fastenings are provided to retain the column securely on the base plate and resist all moments and forces (except direct compression in the column.) arising during transit, unloading and erection.
- $$\text{Area of slab base} = \frac{\text{axial load in the column}}{\text{permissible compressive stress in concrete}}$$
- The thickness of a rectangular slab base as per IS : 800-1984.

$$t = \sqrt{\frac{3w}{\sigma_{bs}}\left(a^2 - \frac{b^2}{4}\right)}$$



where t = the slab thickness (mm)

w = the pressure or loading on the underside of the base (MPa)

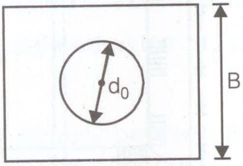
a = the greater projection of the plate beyond the column (mm) = max. (α, β).

b = the lesser projection of the plate beyond the column (mm) = min. (α, β)

σ_{bs} = the permissible bending stress in slab bases
= 165 MPa for flanged beams
= 185 MPa for solid beams

- The thickness of a square slab base plate under a solid round column.

$$t = 10\sqrt{\frac{90W}{16\sigma_{bs}} \times \frac{B}{(B - d_0)}}$$



W = the total axial load (kN)
B = the length of the side of cap or base (mm)
d_0 = the diameter of the reduced end (if any) of the column (mm).

- The cap or base plate should not be less 1.5 (d_0 + 75) mm in length or diameter.

■■■