1. STRUCTURAL FASTENERS

RIVETING

The size of the rivet is the diameter of the shank.

(a) **Gross dia of rivet or dia of hole**

$\boxed{d' = d + 1.5\,mm}$ for $d \leq 25$ mm

and $\boxed{d' = d + 2.0\,mm}$ for $d > 25$ mm

where d = Nominal dia of rivet

d' = Gross dia of rivet or dia of hole.

> **NOTE** For strength calculation effective diameter is taken into account. This is based on the assumption that rivet fills the hole completely.

(b) **Unwins formula**

$\boxed{d_{mm} = 6.05\sqrt{t_{mm}}}$ where, d_{mm} = dia of rivet in mm

t_{mm} = thickness of plate in mm.

BOLTED JOINTS

Bolts may be used in place of rivets for structure not subjected to vibrations. The following types of bolts are used in structures:

(i) **Black bolts**

- Hexagonal black bolts are commonly used in steel works.
- They are made from low or medium carbon steels.
- They are designated as black bolts $M \times d \times l$ where d = diameter, and l = length of the bolts.

(ii) **Precision and Semi Precision Bolts**

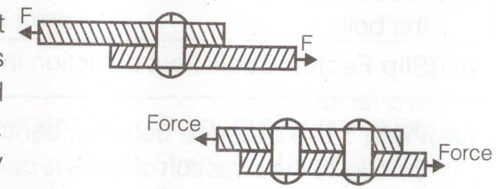
- They are also known as close tolerance bolts.
- Sometimes to prevent excessive slip, close tolerance bolts are provided in holes of 0.15 to 0.2 mm oversize. This may cause difficulty in alignment and delay in the progress of work.

- **Types of Riveted and Bolted Joints**

There are two types of riveted or bolted joints.

(i) **Lap joint**

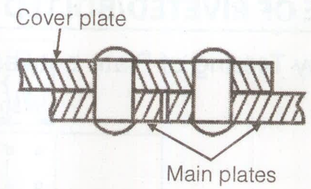
- The lap joint is that in which the plates to be connected overlap each other.
- The lap joint may have single-row, staggered or chain riveting.



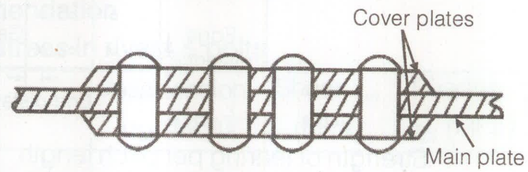
Lap joint

(ii) **Butt Joint**

- The butt joint is that in which the plates to be connected butt against each other and the connection is made by providing a cover plate on one or both sides of joint.



Single-riveted single-cover butt joint



Double-riveted double-cover butt joint

- The butt joint may have a single row or staggered or chain riveting.

> **Remember**
> (i) **Nominal diameter (d):** The diameter of the shank of a rivet before riveting, is called the nominal diameter. For a bolt, the diameter of the unthreaded portion of the shank is called its nominal diameter.
> (ii) **Effective diameter or gross diameter:** The effective or gross diameter of a rivet is equal to the diameter of the hole it fills after riveting. For a bolt, the nominal diameter is same as the gross diameter.
> (iii) **Net area:** The net area of a bolt is the area at the root of the thread.
> (iv) **Gauge:** A row of rivets parallel to the direction of force is called a gauge line. The normal distance between two adjacent gauge line is called the gauge.

(v) **Edge distance:** It is the distance between the edge of a member or cover plate and the centre of the nearest rivet hole.

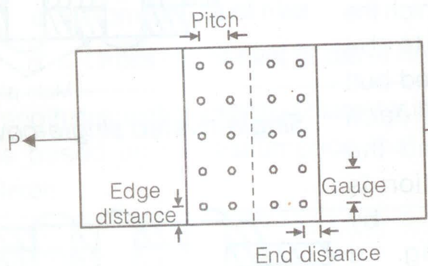
(vi) **Proof load :** Initial tension in HSFG bolts is known as proof load of the bolt.

(vii) **Slip Factor:** Coefficient of friction in friction type joint is known as slip factor.

(viii) **Pitch :** The distance between centres of any two adjacent rivets parallel to the direction of force is called pitch. Diagonal pitch is the distance between centres of any two adjacent rivets in the diagonal direction is called diagonal pitch.

FAILURE OF RIVETED/BOLTED JOINTS

(i) **By Tearing of Plate between rivets**



Strength of tearing per pitch length

$$P_t = (P - d')\, t \times f_t$$

where, f_t = Permissible tensile stress in plates

t = Thickness of plate

d' = Dia of hole (gross dia of rivet)

p = Pitch

(ii) **Strength of rivet in single shear** $P_s = \frac{\pi}{4}(d')^2 . f_s$

(iii) **Strength of rivet in double shear**

$$P_s = 2 \times \frac{\pi}{4} . d'^2 . f_s$$

where, f_s = allowable shear stress in rivets

d' = dia of hole.

(iv) **Failure due to bearing or crushing of rivet or plates**

Strength of rivet in bearing

$P_b = f_b . d' . t$ where, f_b = bearing strength of rivet.

NOTE

Shearing strength of joint is simply the sum of shearing strength of individual rivets.

Bearing strength of joint is simply sum of bearing strength of individual rivets in the joints.

EFFICIENCY OF JOINTS (η)

$$\eta = \frac{\text{Minimum}\{P_s, P_b, P_t\}}{P}$$

where, P_s = Strength of joint in shear

P_b = Strength of joint in bearing

P_t = Strength of joint in tearing

P = Strength of plate in tearing when no deduction has been made for rivet holes

$= p.t.f_t$

- Rivet value $R_V = \text{minimum}\begin{cases} P_s \\ P_b \end{cases}$
- Number of rivet, $n = \frac{\text{Force}}{R_V}$
- **I.S. 800; 1984 Recommendation**

Maximum permissible stress in rivets & bolts

Type of fastener	Axial tension, σ_{at} (MPa)	Shear, τ_{vf} (MPa)	Bearing, σ_{pf} (MPa)
(i) Power driven			
(a) Shop rivets	100	100	300
(b) Field rivets	90	90	270
(ii) Hand driven rivets	80	80	250
(iii) Close tolerance and turned bolts	120	100	300
(iv) Bolts in clearance holes	120	80	250

- Rivet diameter, Pitch

Minimum pitch	2.5 times of nominal diameter of the rivet
Maximum pitch for	
(i) any two adjacent rivets (including tacking rivets)	32t or 300 mm, whichever is less
(ii) rivets lying in a line parallel to the force in the member:	
(a) in tension	16t or 200 mm. whichever is less
(b) in compression	12t or 200 mm, whichever is less

where t = thickness of thinner outside plate

PERMISSIBLE STRESSES

Case	Permissible stress
Axial tension and compression	$0.60\ f_y$
In bending	$0.66f_y$
In bearing(ex-at support)	$0.75f_y$
In shear	max. permissible avg. $= 0.40f_y$ max. permissible $= 0.45\ f_y$

MAX PERMISSIBLE DEFLECTIONS

(a) Max permissible horizontal and verticle deflection $= \frac{\text{Span}}{325}$(WSM)

(b) Max permissible deflection when supported elements are susseptible to cracking $= \frac{\text{Span}}{360}$(LSM)

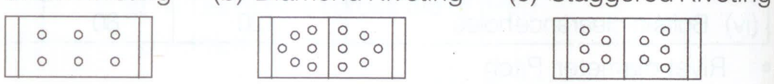
(c) Max permissible deflection when supported element are not susseptible to cracking $= \frac{\text{Span}}{300}$(LSM)

Remember

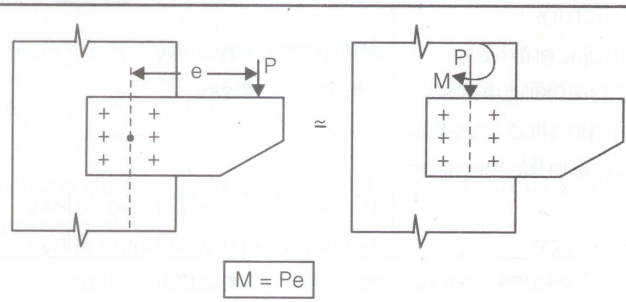
1. When wind and earthquake loads are considered permissible stresses in steel structures are increased by 33.33% and in rivets and welds are increased by 25%.
2. By providing proper edge distance, we can prevent shear failure, splitting failure and bearing failure of plates.

ARRANGEMENT OF RIVETS

(a) Chain Riveting (b) Diamond Riveting (c) Staggered Riveting

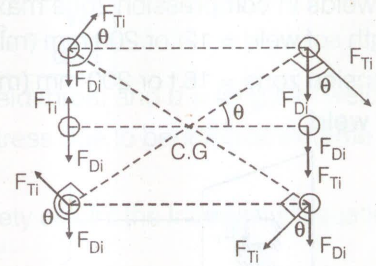


ECCENTRIC CONNECTIONS



(i) $F_{Di} = \frac{P.A_i}{\Sigma A_i}$

(ii) $F_{Ti} = \frac{Per_i}{\Sigma A_i r_i^2} A_i$



Special Case: When all the rivets are of same diameter then.

(a) $F_{Di} = \frac{P}{n}$ (b) $F_{Ti} = \frac{Per_i}{\Sigma r^2}$ or $F_{Ti} = \frac{Mr_i}{\Sigma r^2}$

(iii) $Fr_i = \sqrt{(F_{Di})^2 + (F_{Ti})^2 + 2F_D.F_T \cos\theta} \le R_v$

where, F_{Di} = Direct force in i^{th} rivet.

F_{Ti} = Force in i^{th} rivet drew to torsional moment

r_i = Distance of i^{th} rivet from C.G.

A_i = Area of i^{th} rivet $= \frac{\pi}{4}(d_i)^2$

F_{Di} = Always acts in the direction of applied load P.

F_{Ti} = Always acts perpendicular to the line joining C.G. of rivet group and the rivet under consideration.

F_{ri} = Resultant force in i^{th} rivet.

***Note:** Most critical rivet is one for which θ is minimum and r is maximum.*

Angle b/w fusion faces	Value of k
60°-90°	0.70
91°-100°	0.65
101°-106°	0.60
107°-113°	0.55
114°-120°	0.50

- **Minimum size of weld**

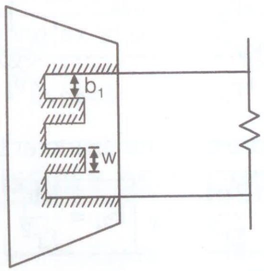
  It depends upon thickness of thicker plate

Thickness of thicker plate	Minimum size
0-10 mm	3 mm
11-20 mm	5 mm
21-32 mm	6 mm
>32 mm	8 mm

For welds in compression zone max clear spacing between effective length sof weld = 12t or 200 mm (minimum).

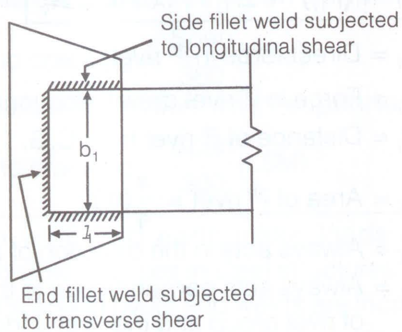
In tension zone = 16 t or 200 mm (minimum)

- **Slot weld**



$b_1 \nless 2t$
$w \nless 3t$ or 25 mm

- **Side fillet weld**



(a) $l_1 \nless b_1$

(b) $b_1 \ngtr 16t$ to make stress distribution uniform

(c) if $b_1 > 16t$ use end fillet weld.

WELDED CONNECTION

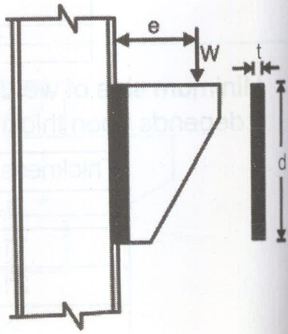
- **Permissible Stresses**

(a) Tensions and compression on section through the throat of butt weld = 150 N/mm^2

(b) Shear on section through the throat of butt or fillet weld = 108 N/mm^2 ≅ 110 N/mm^2

Throat thickness t = k × size of weld

- **Butt-welded Joint Loaded Eccentrically**
  - Let thickness of weld throat = t, and length of weld = d



- Shear stress at weld, $P_s = \frac{W}{d \times t}$

Where t = thickness of weld throat and d = length of weld.

- Tensile or compressive stress due to bending at extreme fibre,

$P_b = \frac{6M}{t \times d^2}$ For the safety of joint the interaction equation.

$$\left[\left(\frac{P_s}{\text{Permissible shear stress in weld}}\right)^2 + \left(\frac{P_b}{\text{Permissible tensile stress in weld}}\right)^2\right] \le 1$$

- **Equivalency Method**

$\sqrt{P_b^2 + (3P_s)^2} \le 0.9f_y$ (based on max distortion energy theory)

Permissible bending stress for flanged section = 165 N/mm^2 = 0.67f_y

For solid section (▨, ◍, ▲) permissible bending stress is 185 N/mm^2

FILLET-WELDED JOINT LOADED ECCENTRICALLY

There can be two cases:

(i) Load not lying in the plane of the weld

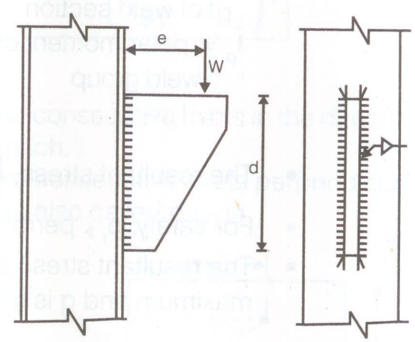
(ii) Load lying in the plane of the weld

(i) Load not lying in the plane of the weld :

- Let thickness of weld throat = t and total length of weld = 2 × d
- Vertical shear stress at weld,

$p_s = \frac{W}{2d \times t}$

- Horizontal shear stress due to bending at extreme fibre,



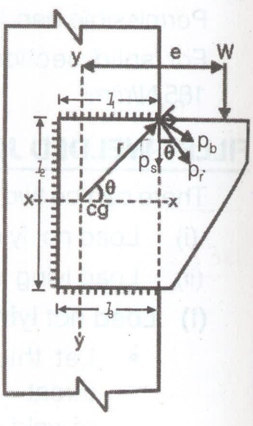
$$p_b = \frac{M}{I} \times y = \frac{(W \times e) \times d/2}{\frac{2 \times t \times d^3}{12}}$$

$$p_b = \frac{3We}{td^2}$$

- Resultant stress, $p_r = \sqrt{p_s^2 + p_b^2}$

- The value of p_r should not exceed the permissible shear stress p_q (= 108 MPa) in the weld.
- For design of this connection, the depth of weld may be estimated approximately by $d = \sqrt{\dfrac{6 \times W \times e}{2 \times t \times p_b}}$

(ii) **Load lying in the plane of the weld:** Consider a bracket connection to the flange of a column by a fillet weld as shown in figure



- Vertical shear stress at weld, $p_s = \dfrac{W}{l \times t}$

where,

$l(l_1 + l_2 + l_3)$ = the length of weld

and t = thickness of the throat

- Torsional stress due to moment, at any point in the weld, $p_b = \dfrac{T \times r}{I_p}$

where,

T = torsional moment = W × e

r = distance of the point from cg of weld section

I_p = polar moment of inertia of the weld group

$= I_x + I_y$

- The resultant stress, $p_r = \sqrt{p_s^2 + p_b^2 + 2p_s p_b \cos\theta}$
- For safety, $p_r \ngtr$ permissible stress in fillet weld, i.e. 108 MPa.
- The resultant stress p_r will be maximum at a point where r is maximum and q is minimum.

■■■