SAMPLE STUDY MATERIAL

Postal Correspondence Course

GATE, IES & PSUs

Civil Engineering

STEEL STRUCTURES

ENGINEERS INSTITUTE OF INDIA
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STEEL STRUCTURES

CONTENT

CHAPTER-1

STRUCTURAL STEEL, LOADS AND STRESSES

Structural Steel:

Main components of steel are: (i) Metallic iron, (ii) Carbon and others like Si, Cr, Mn, Cu etc.

- Generally steel consists of more than 98% of iron and carbon content 0.04% to 2.25%
- **Cast iron** has low carbon content, which makes its brittle.
- **Wrought iron** has high carbon content, which imparts its tensile strength.
- **Steel** has carbon content intermediate between cast iron and wrought iron.
- Depending upon chemical composition, steel is classified as:

  (i) Mild steel
  (ii) Medium carbon steel
  (iii) High carbon steel
  } Are Knows as structural steel and is used in steel structure.

  (iv) Low alloy steel

  (v) High alloy steel

- **Mild steel** is used for manufacture of rolled steel section, rivets and bolts.
- **Physical properties** of mild structure are.

  (i) Mass : 7850 Kg/m^3

  (ii) Young's modulus of Elasticity (E): 2.04×10^5 N/mm^2 or MPa

  (iii) Modulus of rigidity (G): 0.785×10^5 N/mm^2

  (iv) Poisson's ratio (μ) : 0.3 (in elastic range)
  : 0.5 (in plastic range)

  (v) Co-efficient of thermal expansion or contraction : 12×10^{-6}/ºC

Table : Chemical Composition of Structural Steels

S. No.	Quality of Steel	Designation	I.S. Code	Maximum percentage C	S	P	Mn	Si	Tensile strength (N/mm^2)
1.	Standard structural C = 0.2–0.35%	Fe-410S	226	0.23	0.055	0.055	—	0.10	410
2.	Structural ordinary	Fe 310	1977	0.23	0.07	0.07	—	—	310
		Fe 410-O	1977	0.23	0.07	0.07	—	—	410
3.	Weldable	Fe 410-H	2062	0.20	0.055	0.055	1.0	—	410
		Fe 440 HT	8500	0.25	0.055	0.055	1.5	—	440
		Fe 490 HT	8500	0.25	0.04	0.04	1.5	—	490
		Fe 590 HT	8500	0.25	0.05	0.05	1.5	—	590

Fe = steel, C = carbon, S = sulphur, P = phosphorus, Mn = Manganese, Si = silicon

- **Structural Elements of a Steel Structure:** The steel frame work or the skeleton consists of following elements.

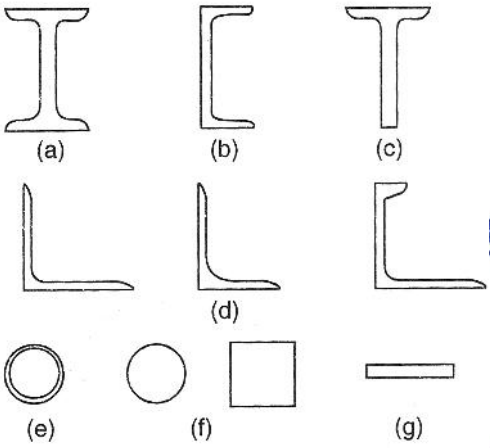
  (*i*) Flexural members – beams or girders

  (*ii*) Tension members – ties

  (*iii*) Compression members – columns, struts

  (*iv*) Torsional members

  The members of the design are made up of commonly used shapes and built by members – made of the common shapes. Following are the common shapes.



(a.) Rolled steel I-section

(b.) Rolled steel channel section

(c.) Rolled steel T-section

(d.) Rolled steel angle section (equal or unequal)

(e.) Rolled steel circular section (solid or hollow)

(f.) Rolled steel bars (circular or rectangular)

(g.) Rolled steel plates

Flexural members: (Beams and Girders) : A beam or girders is a structural component which supports loads normal to its axis. They are both same but girder is primarily used to describe a built up member or a main beam which supports other beams.

Tension Members (Ties) : It is used to resist axial tension. They are usually called ties or hangers. The cross-section of a tension member is important only to the context of its quantity. The shape is immaterial to resist the tensile force.

Compression Members (Columns, Struts): They primarily resist the compressive stress. The shape of a compression member plays an important role in its determination apart from the area required. The material properties also plays an important role in its selection.

Torsional Members: They are primarily provided to resist torsion or twisting forces.

Design Methods : There are mainly two methods according to which the different members are designed. They are

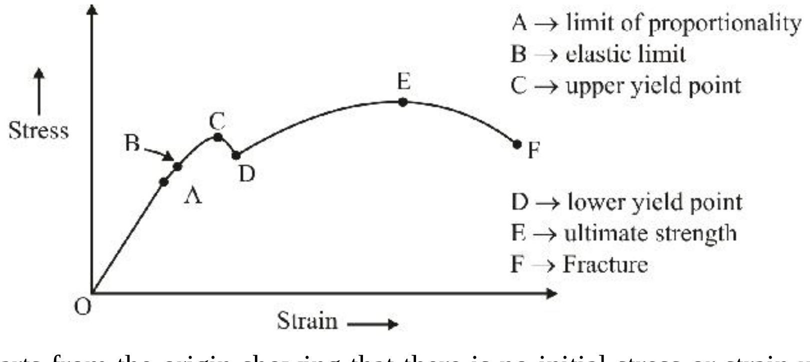
(*i*) Working stress design: Also known as the elastic design method, it assumes that the acceptable behaviour in a steel member is up to the yield stress. It also takes into account the factor of safety.

$$\text{Permissible stress} \leq \frac{\text{Yield stress}}{\text{Factor of safety}}$$

(*ii*) Plastic design: In this method, the material is considered acceptable upto the ultimate load. It is mainly used in the analysis and design of statically indeterminate structure. The factor of safety in this method is known by the name of 'load factor.'

$$\text{Working load} = \frac{\text{Collapse load}}{\text{Load factor}}$$

Stress Strain Relationship for Mild Steel:



The curve starts from the origin showing that there is no initial stress or strain upto point A, Hooke's law is obeyed and stress is proportional to strain. Point A is called the limit of proportionality.

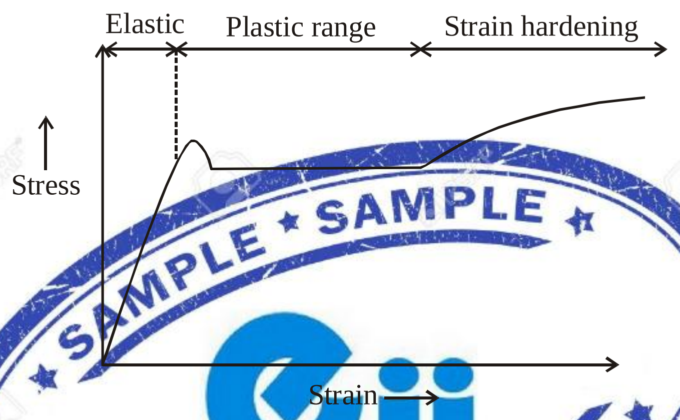
Point B is called the elastic limit. Upto this point if the load is removed, the material returns to its original shape and size, *i.e.*, no strain is left in the specimen.

Beyond point B, the material behaves as a plastic material until point C which is the upper yield point.

After point C the cross-sectional area of the material starts decreasing and the stress decreases to a lower value to point D, called the lower yield point.

Beyond D, the specimen elongates without a considerable increase in stress and reaches a maximum value of stress called the ultimate strength. This is denoted by point E.

After point E, necking of the material starts and the cross-sectional area decreases at a rapid rate. At last, the material fractures at point F.



This figure is an enlarged view of a part of the graph given above. It shows that the range of working stress design is only upto the proportional limit while the range for plastic design is large and upto a strain 10 times than what occurred upto the proportional limit. Beyond plastic range is the strain hardening for which a structure is not designed.

Loads : The primary purpose of any structure is that it should be strong enough to carry all types of foreseeable loads. Various types of loads to which a structure may be subjected fall into three broad categories.

(*i*) Dead loads (*ii*) Live loads and forces (*iii*) Wind load

(*i*) Dead loads : It is the weight of the walls, partitions, roofs, etc. and other permanent construction in the building. Dead loads do not change their position and do not vary in magnitude.

(*ii*) Live loads : It consists of variable loads, due to people, furniture, stores, machinery etc. It is also known as the super-imposed loads. In broader sense, it includes.

- Movable machinery
- Snow load
- Earth pressure
- Earthquake forces
- Thermal forces.

(*iii*) Wind loads : Wind produces wind pressure on the exposed vertical surfaces of wall, towers, etc. and acts horizontally. The wind velocities are measured with the help of anemometers which are installed at a height of 10 to 30 meters.

Permissible Stresses:

1. Axial tensile stress:

Permissible axial tensile stress $(\pm_{at})$:

$\boxed{\pm_{at} = 0.6 f_y}$ Where $f_y =$ yield stress of steel (N/mm^2)

2. Axial Compressive Stress:

Permissible axial compressive stress

$\boxed{\pm_{ac} = 0.6 f_y}$ For direct stress in compression of a axially loaded column

Or, According to Rankine's formula:

$$\pm_{ac} = 0.6 \frac{f_{cc} \cdot f_y}{\left[(f_{cc})^n + (f_y)^n\right]^{1/n}}$$

Where, $f_{cc} =$ elastic critical stress in compression $= \frac{®^2 E}{a^2}$

$a =$ Slenderness ratio $= \frac{l}{r}$

$n =$ 1.4

E = Young's modulus

The value of $\pm_{ac}$ shall exceed neither of the above two values.

3. Bending Stress:

- Permissible bending stress in tension or in compression:

$\boxed{\pm_{bt} \text{ or } \pm_{bc} = 0.66 f_y}$

- Permissible bending compressive stress in beams and plate girders:

$$\pm_{bc} = 0.66 \frac{f_{cb} \cdot f_y}{\left[(f_{cb})^n + \left(f_y\right)^n\right]^{1/n}}$$

Where, $f_{cb} =$ Elastic critical stress in bending.

n =1.4

4. Shear Stress:

- Permissible shear stress, $\boxed{2_{vm} = 0.45 f_y}$

5. Bearing Stress:

- Permissible bearing stress, $\boxed{\pm_p = 0.75 f_y}$

Factor of safety (F.O.S.)F:

- It is defined as the ratio of yield stress to maximum expected stress.

$$\boxed{F = \frac{f_y}{\pm_{\max}}}$$

- I.S. Code permits the value of F as 1.67.

Questions:

1. What is the permissible axial tensile stress for the grade of steel having $f_y = 250 \text{ N/ mm}^2$?

(a) 150 N/ mm^2 (b) 100 N/ mm^2 (c) 200 N/ mm^2 (d) 250 N/ mm^2

2. What is slenderness ratio, λ is terms of efficiency length and radius of gyration ?

(a) $\lambda = \frac{l_e}{r}$ (b) $\lambda = \frac{l_e^2}{r}$ (c) $\lambda = \left(\frac{l_e}{r}\right)^2$ (d) $\lambda = \sqrt{\frac{l_e}{r}}$

3. What is the value of factor of safety permitted by the code for steel structure ?

(a) 1.5 (b) 1.15 (c) 1.67 (d) 1.8

4. In what category of load world a machinery fall?

(a) Dead load (b) Live load (c) Wind load (d) None of the above

5. Till which point, a material remains elastic in nature (not necessarily obeying Hooke's law) ?

(a) upper yield point (b) Lower yield point
(c) Proportional limit (d) Ultimate load

Answers & Explanations

1. **(a)** $\sigma_{at} = 0.6\ f_y$

$$\Rightarrow \sigma_{at} = 0.6 \times 250 = 150 \text{ N/ mm}^2$$

2. (a) **3.** (b) **4.** (b) **5.** (c)

CHAPTER-2

STEELWORK CONNECTIONS

CLASSIFICATION OF CONNECTIONS FOR STRUCTURAL STEELWORK:

1. Riveted Connection
2. Bolted connection
3. Pinned Connection
4. Welded Connection

I. RIVETED CONNECTION:

- **Rivet:** It is made up of a round ductile steel bar piece called shank, with a head at one end.

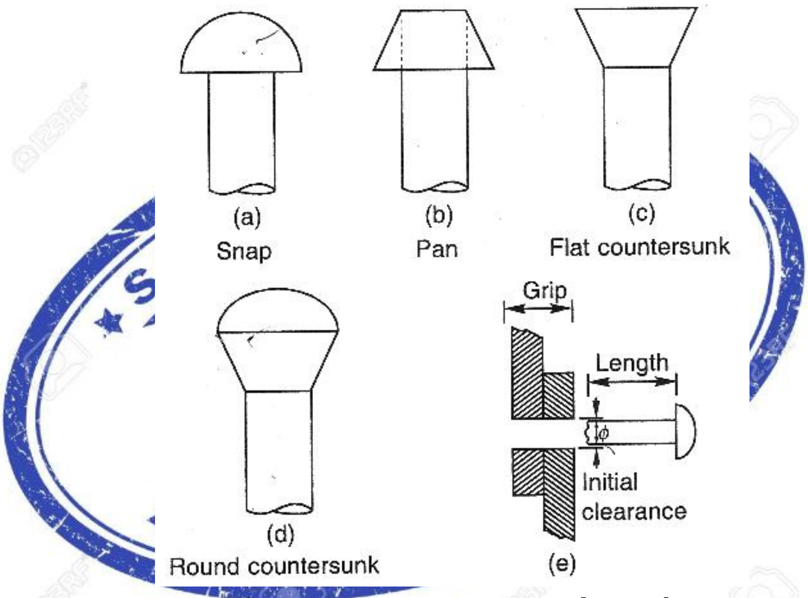
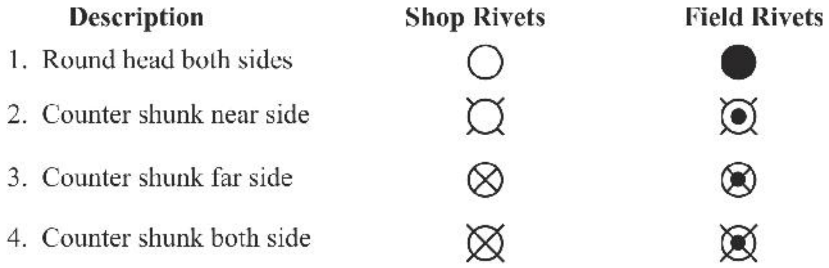


Figure: Rivet Types, Grip and Length

- **Grip** of rivets is equal to the total thickness of plates to be joined by the rivet.
- **Length** of undriven rivet is the sum of :
  (1) Grip (2) Length required for the head to be formed (3) Additional Length
- **Rivet** is classified as :
  (i) Hot driven field rivets
  (ii) Hot driven shop rivets
  (iii) Cold driven rivets-for smaller range of diameter –12mm –22mm.
  Strength of cold driven rivets is more than hot driven rivets.
  (iv) Hand driven rivets
  (v) Power driven rivets

Symbols:



Definition:

- **Nominal diameter** $(¤_{n})$ **:** It is the diameter of unheated rivet, before driving.
- **Gross diameter** $(¤_{gross})$: It is the diameter of rivet in the hole, after driving.
- **Pitch (p):** It is the distance between centers of two adjacent rivets in a row.
- **Gauge line/Rivet line:** It is the line or rivets parallel to the direction of stress.
- **Gauge distance or Gauge (g):** It is the perpendicular distance between two adjacent gauge lines. Also known as **back pitch.**

Note:

Generally, pitch is taken as the centre to centre distance between rivets measured along the long direction and gauge is the centre to centre distance between rivets measured along the short direction.

- **Edge Distance:** It is the distance of the edge of the member or cover plates from the centre of extreme rivet hole.
- **Lap:** It is the distance normal to the joint between edges of the overlapping plates in a lap joint or between the joint and the end of cover plates in a butt joint.

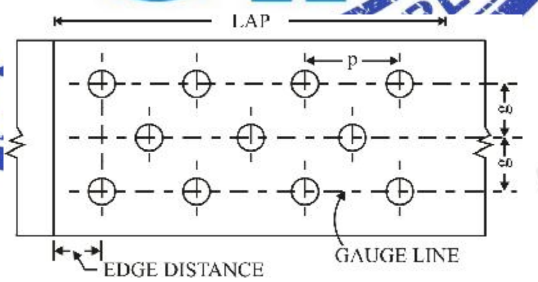


Figure: Definition Sketch

Permissible Stresses:

Table: Permissible Stresses in Rivets

Type of rivet	Axial tension (MPa)	Shear (MPa)	Bearing (MPa)
Power drive	100	100	300
Hand drive	80	80	250

- For field rivets, the permissible stresses are reduced by 10%
- Bearing stress of a rivet should not exceed by value of f_y(yield stress) and 1.2 $f_y$for hand driven and power driven rivets respectively.

Types of Riveted Joint:

1. **Lap Joint:** The two members to be connected are over lapped and connected together. e.g. single riveted, Double riveted.

2. **Butt Joint:** The two members to be connected are placed end to end and additional plates are provided on either one or both sides to connect with main plate. E.g. Single cover butt joint, Double cover butt joint etc.

Note:

- Shear carrying capacity of a rivet in a butt joint is double that of a rivet in lap joint.

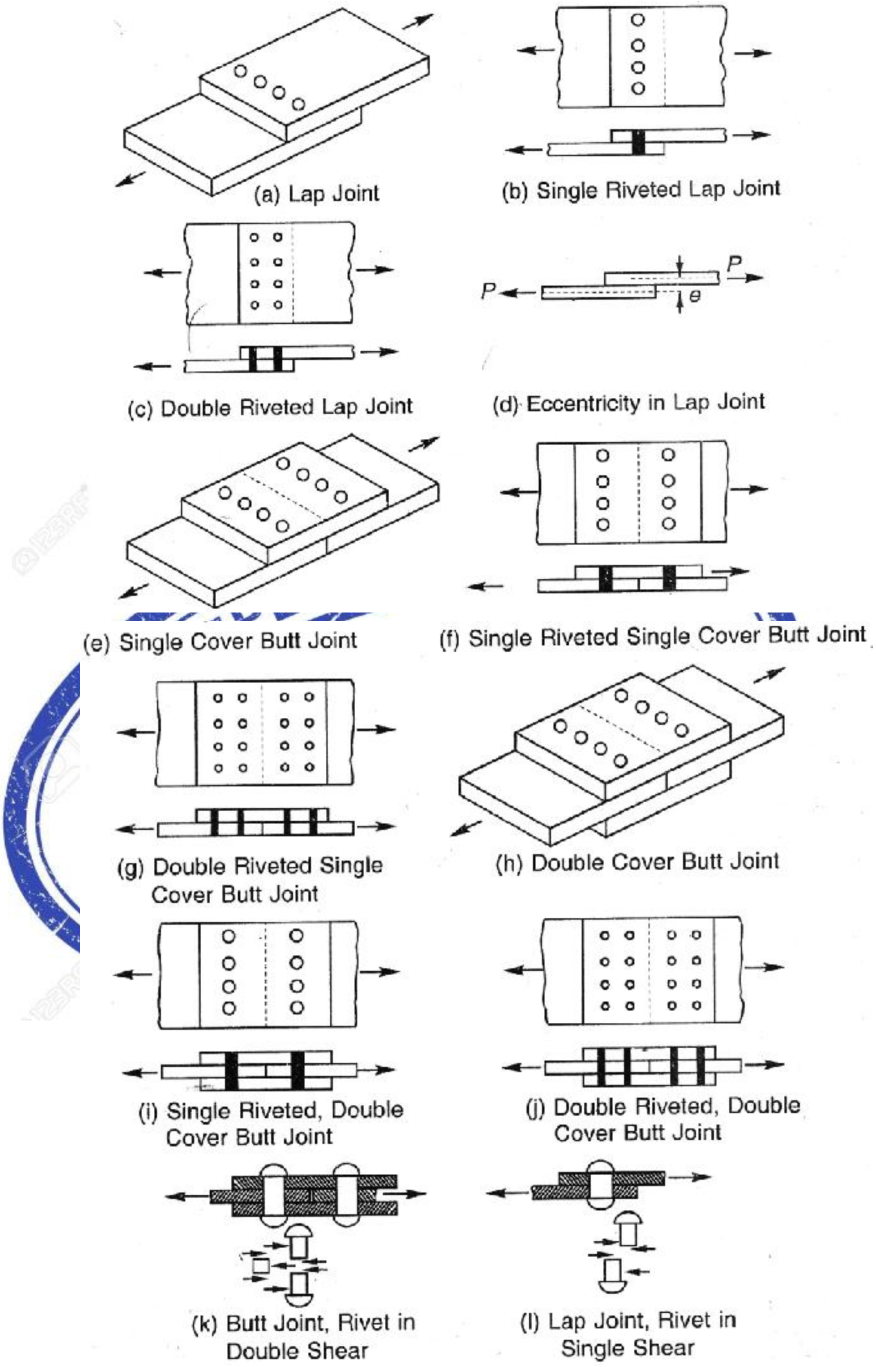


Figure: Types of Riveted joints

Failure of Riveted Joint:

1. **Shear Failure of Rivets:** Shear Stress in the rivet may exceed the working stress in the rivet, which causes failure.
2. **Shear Failure of Rivets:** It occurs when the internal pressures of over-driven rivets are placed at a lesser edge distance.

3. **Tension or tearing failure of plates:** Tensile stress in the plate at the net cross-section may exceed the working tensile stress, which causes failure. It occurs when the rivets are stronger than the plates.
4. **Splitting of plates:** It occurs when the rivets are placed at a lesser edge distance.
5. **Bearing failure of plates:** It occurs when the bearing stress in the plate exceeds the working bearing stress.
6. **Bearing failure of rivets:** It occurs when the plate is strong in bearing.

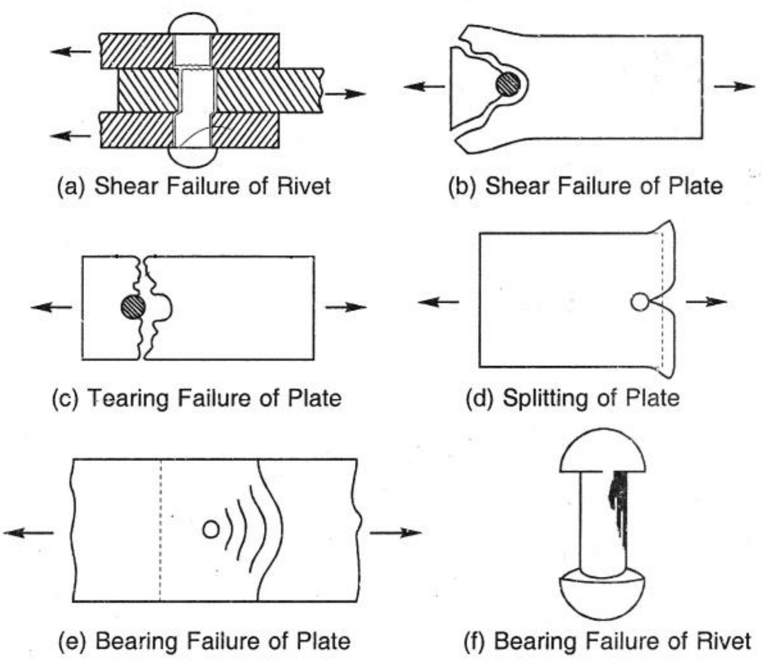
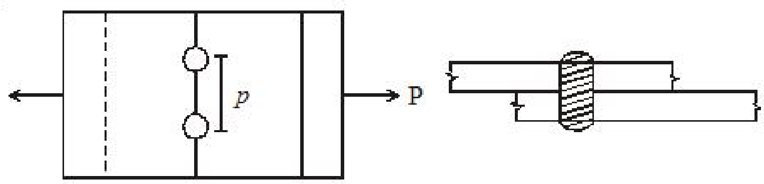


Figure: Failure of Riveted Joints

Modes of Failure and Strength of Rivet Joints

1. Tensile Failure: During tensile failure, the plate tears on application of force more than what is permissible.



$$P_t = \sigma_{at}(p - d) \times t$$

where, $P_t \rightarrow$ force required for a tensile failure per pitch length

$\sigma_{at} \rightarrow$ permissible tensile stress

$p \rightarrow$ pitch

$d \rightarrow$ gross diameter of rivet

$t \rightarrow$ thickness of thinner plate

The force is per pitch length.

Design of Riveted Joint:

Assumption:

(i) Rivets are assumed to be stressed equally.

(ii) Rivet hole is assumed to be filled completely by the rivet.

(iii) Friction between the plates in neglected.

(iv) Shear stress is assumed to be uniformly distributed over the gross cross-sectional area of the rivet.

(v) Stress in a plate is assumed to be uniform.

(vi) Bending of rivet is neglected.

(vii) Bearing stress is uniform between plates and rivets.

Specification:

As per IS code: IS: 800-1984:

1. **Diameter (¤):**

   Gross diameter (ϕ_g) = Nominal diameter (ϕ_n) + 1.5 mm ;$\phi_n \leq$ 25 mm.

   Gross diameter (ϕ_g) = Nominal diameter (ϕ_n) + 2 mm ;$\phi_n \geq$ 25 mm

2. **Pitch (p):**

   ➢ **Minimum Pitch (p_{min}):**

   $$\boxed{p_{\min} \geq 2.5 ¤_n}$$

   ➢ **Maximum pitch (p_{max}):**

(i) $p_{\max} \leq 16t$ or $200mm\}$ Smaller of these two values for tension members

$p_{\max} \leq 12t$ or $200mm\}$ Smaller of these two values for compression member

Where,

t = thickness of thinner outside plate (mm)

In case of compression member in which forces are transferred through butting faces, $\boxed{p_{\max} \leq 4.5¤}$ for a distance from the abutting faces equal to 1.5 times the width of member.

(ii) $p_{\max}$ (Including tacking rivets) ≤ 32 t **or** 300 mm} Smaller of these two values - **for compression member.**

$p_{\max}$. (Including tacking rivet) when exposed to weather

≤ 16t or 200mm} Smaller of these two values-for compression member

(iii) For a line adjacent and parallel to an edge of an outside plate:

$p_{\max}$. ≤ (100 mm + 4t) **or** 200 mm}, Smaller of these two values.

(iv) When the rivets are staggered at equal intervals and gauge does not exceed 75mm, maximum pitch (p_{max}) as given in (i) and (ii) are increased by 50%

3. **Edge Distance:**

(i) Minimum edge distance should not be less than as given in :

Table: Edge Distance

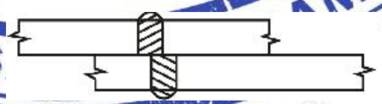
Diameter of hole (mm)	Distance to sheared or hand flame cut edge (mm)	Distance to rolled, machine flame cut, sawn or planed edge (mm)
13.5 and below	19	17
15.5	25	22
17.5	29	25
19.5	32	29
21.5	32	29
23.5	38	32
25.5	44	38
29.0	51	44
32.0	57	51
35.0	57	51

(ii) When two or more plates are connected together a line of rivets or edge distance should not be more then (37 mm + 4*t*). And if the joint is not exposed to weather this value may be increased to 12*t*.

4. Tacking Rivets:

- Tacking Rivets are provided to make the sections act in tension, and to prevent buckling in compression members, when two or more sections are in contact.
- These are not subjected to calculated stresses.
- Additional rivets called as tacking rivets are provided when maximum pitch exceeds specified limit.

Shear Failure : This type of failure occurs when the rivet itself fails along its cross-section



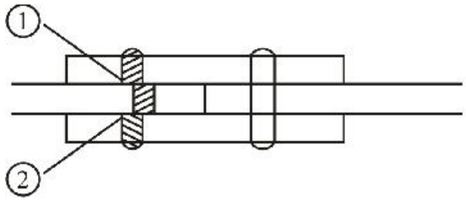
(Single shear)

where, $P_s \rightarrow$ force required for a shear failure per pitch length

$d \rightarrow$ Gross diameter of rivet

$\tau_{vf} \rightarrow$ Permissible shear stress.

The above was an example of single shear because the failure occurs at one interface, *i.e.* only one area is involved in failure. If two interfaces are involved in failure, it is called double shear



(Double shear)

In this case, $P_s = 2 \times \frac{\pi}{4} \times d^2 \times \tau_{vf}$

The above two cases are when there is a single line of rivets. If there are more than one line of rivets. The formula is modified as below.

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau_{vf} \qquad \text{(for single shear)}$$

$$P_s = n \times 2 \times \frac{\pi}{4} \times d^2 \times \tau_{vf} \qquad \text{(for double shear)}$$

where, $n \rightarrow$ no. of line of rivets.

5. Packing:

- Packing or Filler plates are used to make the surfaces of main plates to be jointed.
- Number of rivets carrying calculated shear through a packing shall be increased above the number required by normal calculation by 2.5% for each 2.0 mm thickness of packing and these additional rivets should be placed in the extension of packing.