THEORY & OBJECTIVE

STEEL STRUCTURES

By
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CONTENTS

2 CONNECTIONS

THEORY

2.1 Basis of Design

Connections (or structural joints) may be classified according to the following parameters:

- Method of fastening such as rivets, bolts, and welding — connections using bolts are further classified as bearing or friction type connections
- Connection rigidity — Simple, rigid (so that the forces produced in the members may be obtained by using an indeterminate structural analysis), or semi-rigid

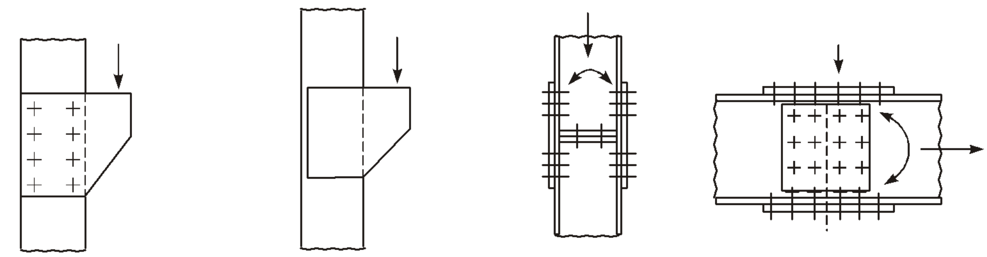
It is desirable to avoid connection failure before member failure due to the following reasons.

- A connection failure may lead to a catastrophic failure of the whole structure.
- Normally, a connection failure is not as ductile as that of a steel member failure.
- For achieving an economical design, it is important that connectors develop full or a little extra strength then the members that it is joining.

According to the IS code, based on connection rigidity, the joints can be defined as follows:

2.1.1 Rigid Connections

Rigid connections develop the full moment capacity of connecting members and retain the original angle between the members under any joint rotation, that is rotational movement of the joint will be very small on these connections.

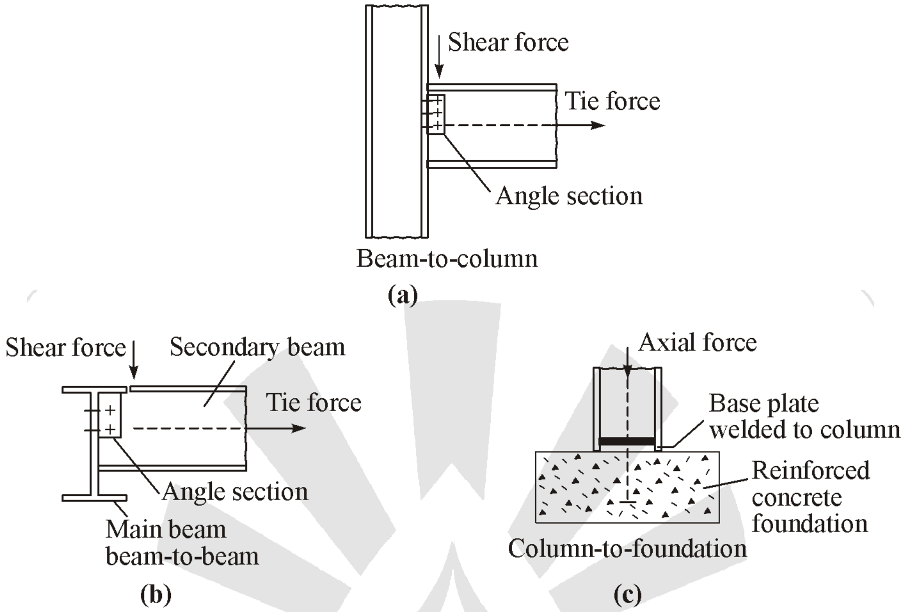


(a) (b) (c) (d)

Example of 'rigid' connections (Martin and Purkiss 1992)

2.1.2 Simple Connections

In simple connections no moment transfer is assumed between the connected parts and hence are assumed as hinged (pinned).



Examples of 'pinned' connections (Martin and Purkiss 1992)

- The rotational movement of the joint will be large in this case. Actually, a small amount of moment will be developed but is normally ignored in the design. Any joint eccentricity less than about 60 mm is neglected.

2.1.3 Semi-Rigid Connections

Semi-rigid connections may have sufficient rigidity to hold the original angles between the members and develop less than the full moment capacity of the connected member.

- In reality, all the connections will be semi-rigid. However, for convenience we assume some of the them as rigid and some as hinge.

2.2 CONNECTION

The following three types of connections may be made in steel structures :

- Riveted
- Bolted
- Welded

2.2.1 Riveted Connections

Riveting is a method of joining together pieces of metal by inserting ductile metal pins called rivets into holes of pieces to be connected and forming a head at the end of the rivet to prevent each metal piece from coming out.

- The diameter of the shank is called the Nominal Diameter.
- When the rivets are heated before driving they are called Hot Driven Field Rivets or Hot Driven

Shop Rivets, depending upon if they are placed in the field or in the workshop.

- The Diameter of the rivets when hot is equal to the diameter of the hole and is called gross diameter.
- The hot rivet becomes plastic, expands and fills the rivet hole completely in the process of forming a head at the other end. On cooling, the rivet shrinks both in length and diameter.
- Rivet holes are made in the structural members to be connected by punching or by drilling. The size of rivet hole is kept slightly more (1.5 to 2.0 mm) than the size of rivet.
- After the rivet holes in the members are matched, a red hot rivet is inserted which has a shop made head on one side and the length of which is slightly more than the combined thicknesses of the members to be connected.
- Then holding red hot rivet at shop head end, hammering is made.
- It results in to expansion of the rivet to completely fill up the rivet hole and also into formation of driven head.
- Desired shapes can be given to the driven head.
- The riveting is done may be in the workshops or in the field.

Riveting has the following disadvantages :

- High level of noise pollution.
- Needs heating the rivet to red hot.
- Inspection of connection is a skilled work.
- Removing poorly installed rivets is costly.
- High labour cost

Production of weldable quality steel and introduction of high strength friction grip bolts have replaced use of rivets.

Design procedure for riveted connections is same as that for bolted connection except that the effective diameter of rivets may be taken as rivet hole diameter instead of nominal diameter of rivet

IS 800-2007 do not discuss riveted connection, it is consider in IS 800:1984

2.2.2 Bolted Connections

A bolt is a metal pin with a head formed at one end and shank threaded at the other in order to receive a nut.

Bolts are used for joining together pieces of metals by inserting them through holes in the metal and tightening the nut at the thread ends.

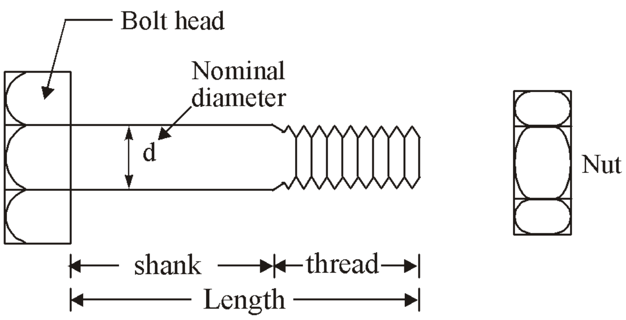


Fig. : Bolt and Nut

2.3 Classification of Bolts

Bolts are classified as :

- Unfinished (black) bolts
- Finished (turned) bolts
- High strength friction grip (HSFG) bolts

2.3.1 Unfinished / Black Bolts

- These bolts are made from MILD steel rods with square or hexagonal head. The shank is left unfinished i.e. rough as rolled.
- In structural elements to be connected holes are made larger than nominal diameter of bolts.
- As shank of black bolts are unfinished, the bolts may not establish contact with structural member at entire zone of contact surface.
- Joints remain quite loose resulting into large deflections.
- These bolts are used for light structures under static loads such as trusses, bracings and also for temporary connections required during erections.
- It is not recommended for connection subjected to impact, fatigue or dynamic loading.
- Bolt of property class 4.6 means, ultimate strength is 400 N/mm^2 and yield strength is

$$400 \times 0.6 = 240 \text{ N/mm}^2$$

- If a bolt is designated as M16, M20, M24, M30, it means shank dia of 16 mm, 20 mm, 24 mm, 30 mm respectively.

2.3.2 Finished/Turned Bolts

- These bolts are also made from mild steel, but they are formed from hexagonal rods, which are finished by turning to circular shape.
- Tolerance available for fitting is quite small (0.15 mm to 0.5 mm).
- It needs special methods to align bolt holes before bolting.
- As connection is more tight, it results in to much better bearing contact between the bolts and holes. These bolts are used in special jobs like connecting machine parts subjected to dynamic loadings.

2.3.3 High Strength Friction Grip (HSFG) Bolts (High Strength Bolt)

- Made from bars of medium carbon steel.
- Normally class 8.8 and 10.9 are commonly used
- Less ductile than black bolts
- Material of the bolt does not have well-defined yield point. In stead of yield stress, proof load is used
- As per IS 800 : 2007 proof load is taken as 0.7 × ultimate tensile stress of bolt
- M16. M20. M24. M30. are generally used
- designated like 8.8S, 10.9S, where, S denotes high strength bolt,
- Percentage elongation of these bolts at failure is approx 12%

- Special techniques are used for tightening the nuts to induce specified initial tension in the bolts, which caused sufficient friction between the flaying forces.
- These bolts with induced initial tension as called high strength friction grip (HSFG) bolts.
- Due to friction, the sleep in the joint is eliminated hence, connection in this case is called nonslip connection or friction type connections.

Note : Black bolt connection → bearing type connection

- Induced initial tension in bolt is called proof-load
- Coefficient of friction is called slip factor
- HSFG bolts provide rigid connection as no slip is involved.
- As forces are transferred by friction only, bolt is not subjected to shear or bearing
- Due to high strength smaller number of bolts are used and hence material requirement of joints reduces
- Since under working load, bearing does not came into play, size of holes can be larger for case of erection and to take care of lack of fit.
- Since the load causing fatigue will be within proof load, the nuts are prevented from loosening and hence fatigue strength of joint will be greater and better than welded and riveted joints.
- Since loads are transferred by friction, there is not stress concentration in the holes.

2.4 Classification of Bolts Based on Method of Load Transfer

On the basis of load transfer in the connection, bolts may be classified as :

- Bearing type
- Friction grip type

Unfinished (black) bolts and finished (turned) bolts are bearing type since they transfer shear force from one member to other member by bearing, whereas HSFG bolts belongs to friction grip type since they transfer shear by friction.

2.5 Terminology Used in Bolted Connection

2.5.1 *Pitch of the Bolts (p)*

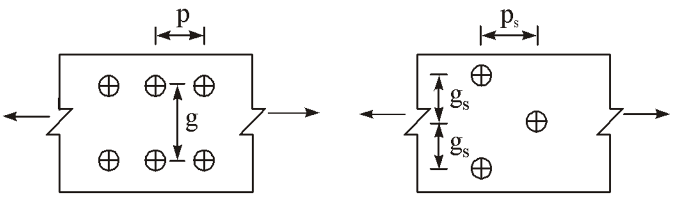
It is the centre to centre spacing of bolts in a row, measured in the direction of load.

2.5.2 *Gauge (g)*

It is the distance between the two consecutive bolts of adjacent rows and is measured at right angle to the direction of load.

2.5.3 *Staggered Pitch (p_s)*

It is the centre to centre distance of staggered bolts measured in the direction of load.



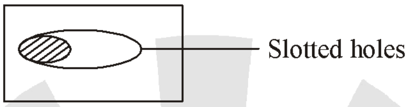
2.5.4 Diameter of Bolt Hole

Diameter of bolt hole is larger than the nominal diameter (shank diameter) of the bolt to facilitate erection and to allow for acurances in fabrication.

Holes are

standard clearance hole → normal

oversized holes (i.e. holes of size larger than standard clearance hole) → used in slip resistant connection.



Short and long slot → used in slip resistant connection

Following table gives the diameter of holes for bolts.

2.5.5 Clearances for Fastener (Bolt) Holes

Nominal Size of Fastener, d mm	Size of the hole =Nominal diameter of the fastener +clearances mm			
	Standard clearance in diameter and width of slot	Over size clearance in diameter	Clearance in the length of the slot	
			Short slot	Long slot
2.	3.	4.	5.	6.
12-14	1.0	3.0	4.0	2.5 d
16-12	2.0	4.0	6.0	2.5 d
24	2.0	6.0	8.0	2.5 d
Larger than 24	3.0	8.0	10.0	2.5 d

From the above table :

Diameter of Normal Bolt Holes are :

Nominal size of Bolts in mm	12	14	16	20	22	24	30	36
Diameter of Bolt hole in mm	13	15	18	22	24	26	33	39

2.5.6 Clearances for Fastener (Bolt) Holes

Gross diameter of rivet = nominal diameter (ϕ) + 1.5 if $\phi \le 25$mm

Gross diameter of rivet = nominal diameter (ϕ) + 2.0 if $\phi > 25$mm

If nominal diameter of rivet is not given then from Unwin's formula

$$\phi = 6.01\sqrt{t}$$

2.5.7 Area of Bolt at Root (A_{nb})

Area of Bolt at root of the thread is less than that at shank of the Bolt. It is taken approximately equal to 0.78 times the shank area i.e.

$$A_{nb} = 0.78 \times A_{sb}$$

where A_{sb} = Area of bolt at shank

$$= \frac{\pi}{4}d^2$$

d = Nominal diameter of Bolt (Shank diameter)

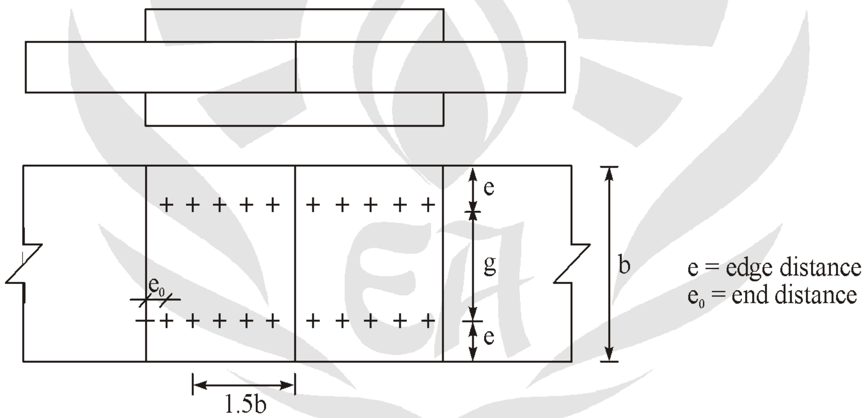
A_{nb} = Area of bolt at root

2.6 IS 800-2007 Specifications for Spacing and Edge Distances of Bolt Hole

Pitch 'p' shall not be less than 2.5 d, where d is the nominal diameter of bolt.

Pitch 'p' shall not be more than

- 16 t or 200 mm, whichever is less, in case of tension members.
- 12 t or 200 mm, whichever is less, in case of compression members where t is the thickness of thinner plate.
- In case of staggered pitch, pitch may be increased by 50 percent of values specified above provided gauge distance is less than 75 mm.
- In case of compression member where forces are transferred through butting faces, i.e.,(butt joints), maximum pitch is to be restricted to 4.5 d for a distance of 1.5 times the width of plate from the butting surface. (Refer Figure Below).



- The gauge length 'g' should not be more than 100 + 4t or 200 mm whichever is less in compression and tension member where t is the thickness of thinner outside plate.

Minimum edge and end distance shall not be

- Less than 1.7 × hole diameter in case of sheared or hand flame out edges.
- Less than 1.5 × hole diameter in case of rolled, machine flame cut, sawn and planed edges.

Maximum edge distance (e) should not exceed

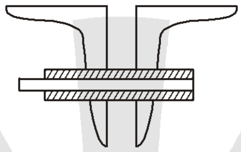
- 12 tε, where $\varepsilon = \sqrt{\frac{250}{f_y}}$ and t is the thickness of thinner outer plate. This recommendation does not apply to fasteners interconnecting the components of back to back tension members.
- Where the members are exposed to corrosive environment max edge distance $\not>$ 40 mm + 4 t, where t is the thickness of thinner connected plate.

Apart from the required bolt from the consideration of design forces, additional bolts called tacking fasteners should be provided as specified below.

- Tacking rivets should be provided.
  - At 32 t or 300 mm, whichever is less, if plates are not exposed to weather,
  - At 16 t or 200 mm, whichever is less, if plates are exposed to weather.

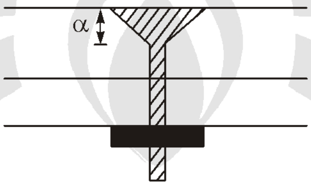
In case of a tension member made up of two flats or angles or tees or channels, tacking rivets are to be provided along the length to connect its components as specified below:

- Not exceeding 1000 mm, if it is tension member.
- Not exceeding 600 mm, if it is compression member.



Countersunk heads

- $\alpha/2$ is neglected in calculating length of fastener in bearing
- for Fastener in tension having countersunk heads, tensile strength is reduced by 33.3% and no reduction in shear strength calculation.



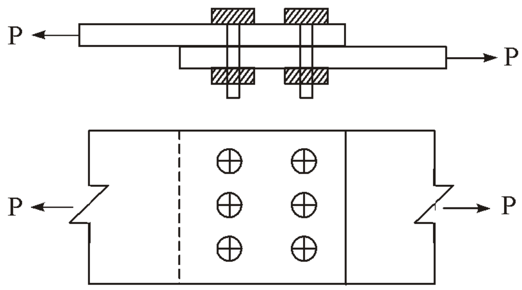
2.7 Various Types of Joints

Types of joints may be grouped into the following two :

- Lap joint
- Butt joint

2.7.1 Lap Joint

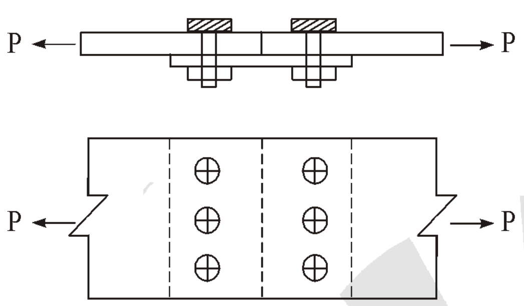
It is the simplest type of joint. In this the plates to be connected overlap one another.



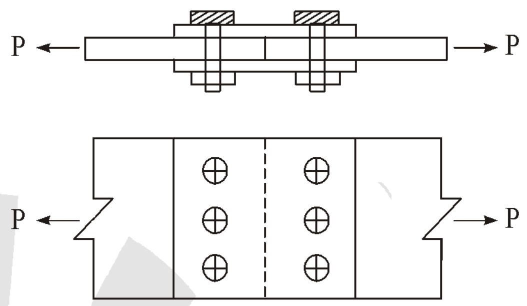
Lap joint

2.7.2 Butt Joint

In this type of connections, the two main plates butt against each other and the connection is made by providing a single cover plate connected to main plate or by double cover plates, one on either sides connected to the main plates.



Single cover butt joint

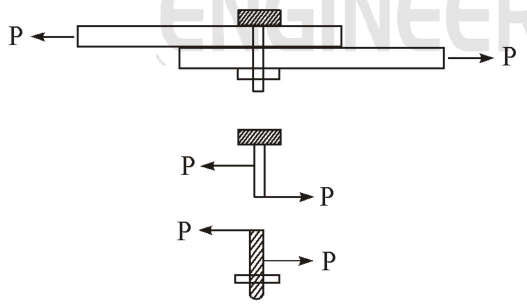


Double cover butt joint

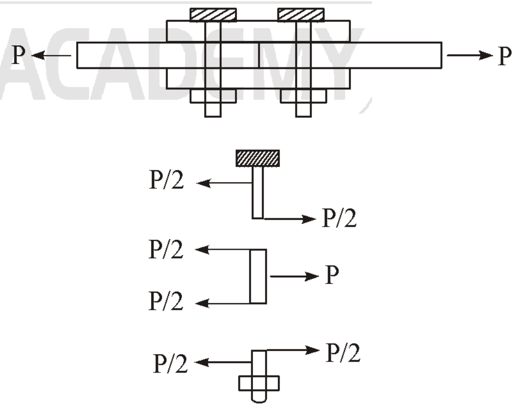
2.8 Types of Actions on Fasteners

Depending upon the types of connections and loads bolts are subjected to the following types of actions:

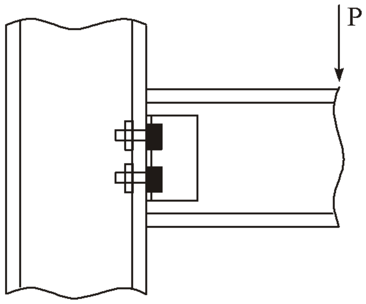
- Only one plane subjected to shear (single shear).
- Two planes subjected to shear (double shear).
- Pure tension
- Pure moment
- Shear and moments in the plane of connection
- Shear and tension



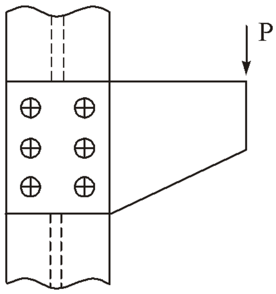
Only one plane subjected to shear



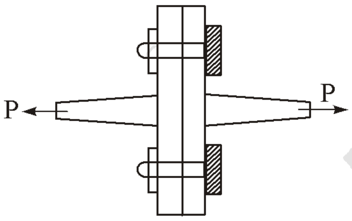
Bolt in double shear



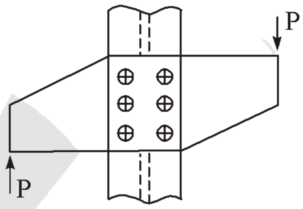
Bolts subjected to shear and tension



Bolts subjected to shear and moments (Torsional)



Bolt in direct tension



Bolts subjected to pure moments (Torsional)

2.9 Assumptions made in Design of Bearing Bolts

The following assumptions are made in the design of bearing (finished or unfinished) bolted connections:

1. The friction between the plates is negligible.
2. The shear is uniform over the cross-section of the bolt.
3. The distribution of stress on the plates between the bolt holes is uniform.
4. Bolts in a group subjected to direct loads share the load equally.
5. Bending stresses developed in the bolts is neglected.

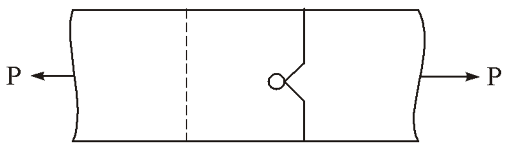
- Assumption 1 is questionable because friction exists between the plates as they are held tightly by bolts. But this assumption results on safer side in the design.
- Actual stress distribution in the plate is not uniform. In working conditions, stresses are very high near bolt holes. But with increase in load the fibres near the hole start yielding and hence stresses at other parts start increasing. At failure the stress distribution is uniform and the ultimate load carrying capacity is given by the net area times the yield stress.
- The fourth assumption is questionable. The bolts far away from centre of gravity of bolt groups are subject to more loads. In the ultimate stage all rivets have to fail, till then redistribution of load will be taking place. Hence the assumption is not completely wrong. IS 800-2007 permits this assumption for short joints (distance between first and the last bolt in the direction of load being less than ($15 \times d$)). For long, a reduction factor has been recommended for finding the strength of joint.

2.10 Design Strength of Plates

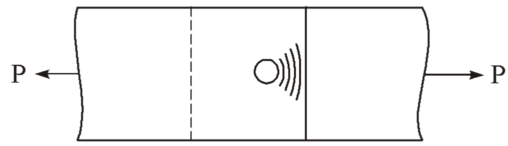
Plates in a joint made with bearing bolts may fail due to any one of the following :

- Shearing or bursting of the edge.
- Crushing of plates.
- Rupture of plates.

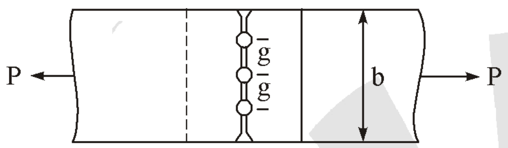
- Block shear failure of plates in tension.
- The brushing or shearing and crushing failures are avoided if the minimum edge/end distances as per IS 800-2007 recommendations are provided.



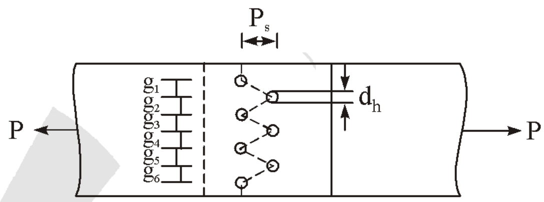
Bursting or shearing of plates



Crushing of plates



Rupture of plates



- **As per IS 800-2007 :** The minimum edge distance and end distances from the centre of any hole to the nearest edge of a plate shall not be less than 1.7 times the hole diameter in case of sheared or hand-flame cut edges; and 1.5 times the hole diameter in case of rolled, machine-flame cut, sawn and planed edges.
- The maximum edge distance to the nearest line of fasteners from an edge of any un-stiffened part should not exceed 12tε,

where $\varepsilon = \sqrt{\frac{250}{f_y}}$ and t is the thickness of the thinner outer plate.

- This would not apply to fasteners interconnecting the components of back to back tension members. Where the members are exposed to corrosive influences, the maximum edge distance shall not exceed 40 mm plus 4t, where t is the thickness of thinner connected plate.
- If the maximum distances are ensured in a joint, the design tensile strength of plate in the joint is the strength of the thinnest member against rupture. This strength is given by

$$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{m1}}$$

where, γ_{m1} = Partial safety factor for failure at ultimate stress = 1.25

f_u = Ultimate stress of the material

A_n = Net effective area of the plate at critical section in zig-zag pattern, which is given by

$$A_n = \left[b - n d_h + \sum \frac{P_{si}^2}{4 g_1} \right] t$$

b = Width of plate

t = Thickness of thinner plate in joint

d_h = Diameter of the bolt hole

g = Gauge length between the bolt holes

p_s = Staggered pitch length between lines of bolt holes

n = Number of bolt holes in the critical section

- It may be noted that, if there is no staggering

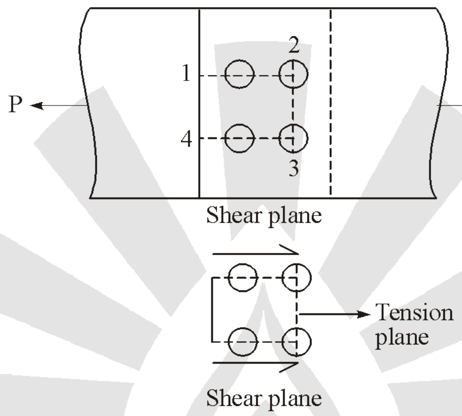
$$P_{si} = 0$$

and hence $A_n = (b - nd_h)t$,

which is the net area at critical section in chain pattern

2.11 Block Shear Strength of Plate

Block shear failure of plate occurs as shown below. It's a combination of yielding and rupture. Block shear failure of a plate occurs along a path involving tension on one plane and shear on a perpendicular plane along the fasteners.



Block shear strength at an end connection is calculated as given below.

- It should be taken as the smaller of

Shear yielding + Tensile rupture

$$T_{db} = \left(\frac{A_{vg} f_y}{\sqrt{3}\,\gamma_{m0}}\right) + \left(\frac{0.9 f_u A_{tn}}{\gamma_{m1}}\right)$$

OR

$$T_{db} = \left(\frac{0.9 f_u A_{vn}}{\sqrt{3}\gamma_{m1}}\right) + \left(\frac{f_y A_{tg}}{\gamma_{m0}}\right)$$

Shear rupture + Tensile yielding

where, A_{vg}, A_{vn} = Minimum gross and net area in shear along a line of transmitted force respectively (1–2 and 4–3 as shown in figure above).

A_{tg}, A_{tn} = Minimum gross and net area in tension from the hole to the toe of the angle or next last row of bolt in plates, perpendicular to the line of force respectively (2–3).

f_u, f_y = Ultimate and yield stress of the material respectively.

γ_{m0}, γ_{m1} = Partial factor of safety in yielding and rupture respectively

$(\gamma_{m0} = 1.1,\ \gamma_{m1} = 1.25)$

OBJECTIVE SHEET

1. Factor of safety adopted by IS: 800-1984 while arriving at the permissible stress in axial compression is

(a) 2.00 (b) 1.00

(c) 1.67 (d) 1.50

2. Maximum size of a fillet weld for a plate of square edge is

(a) 1.5 mm less than the thickness of the plate

(b) one half of the thickness of the plate

(c) thickness of the plate itself

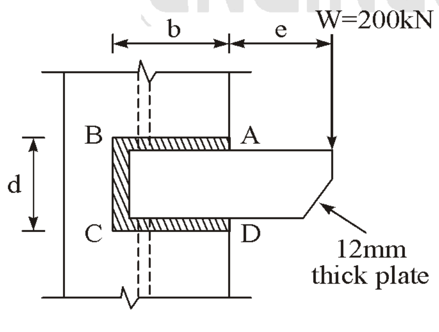
(d) 1.5 mm more than the thickness of the plate

3. In section, shear centre is a point through which, if the resultant load passes, the section will not be subjected to any

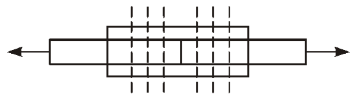
(a) Bending (b) Tension

(c) Compression (d) Torsion

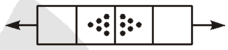
4. A 12mm bracket plate is connected to a column flange as shown in the figure below. The bracket transmits a load of W = 200 kN to the column flange. A 10mm fillet weld is provided along AB, BC and CD. If e = 350 mm, b = 200 mm and d = 600mm, verify if the size of the weld provided is adequate. Allowable shearing stress in the fillet weld can be taken to be 108 MPa.

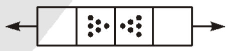


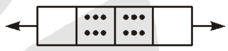
5. Identify the most efficient but joint (with double cover plates) for a plate in tension from the patterns (plan views) shown below, each comprising 6 identical bolts with the same pitch and gauge.

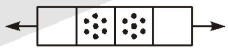


Common elevation

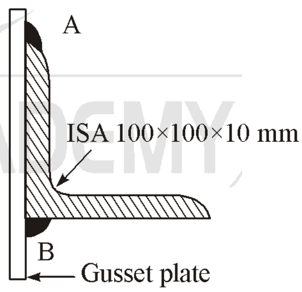
(a) 

(b) 

(c) 

(d) 

6. ISA 100 × 100 × 10mm (Cross sectional area = $1908 mm^2$) is welded along A and B (Refer to figure in the below question) such that the lengths of the weld along A and B are l_1 and l_2 respectively. Which of the following is a possibly acceptable combination of l_1 and l_2



(a) l_1 = 60 mm and l_2 = 150 mm

(b) l_1 = 150mm and l_2 = 60mm

(c) l_1 = 150mm and l_2 = 150 mm

(d) Any of the above, depending on the size of the weld

7. Rivet value is defined as

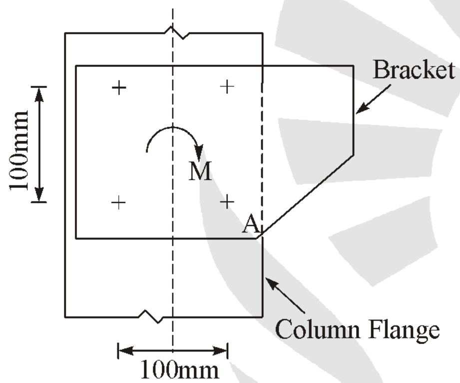
(a) lesser of the bearing strength of rivet and the shearing strength of the rivet

(b) lesser of the bearing strength of rivet and the tearing strength of thinner plate

(c) greater of the bearing strength of rivet and the shearing strength of the rivet

(d) lesser of the shearing strength of the rivet and the tearing strength of thinner plate

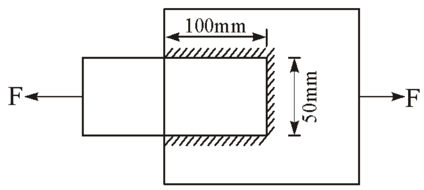
8. A moment M of magnitude 50 kN-m is transmitted to a column flange through a bracket by using four 20 mm diameter rivets as shown in the figure. The shear force induced in the rivet A is



(a) 250 kN (b) 176.8 kN

(c) 125 kN (d) 88.4 kN

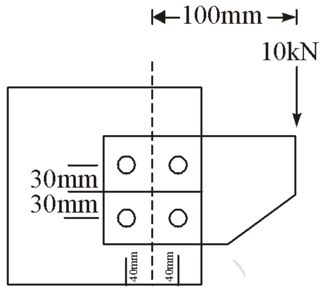
9. A fillet-welded joint of 6 mm size is shown in the figure. The welded surfaces meet at 60-90 degree and permissible stress in the fillet weld is 108 MPa. The safe load that can be transmitted by the joint is



(a) 162.7 kN (b) 151.6 kN

(c) 113.4 kN (d) 109.5 kN

10. A bracket connection is made with four bolts of 10mm diameter and supports a load of 10 kN a an eccentricity of 100 mm. The maximum force to be resisted by any bolt will be



(a) 5 kN (b) 6.5 kN

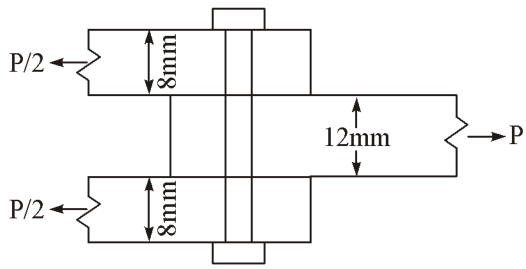
(c) 6.8 kN (d) 7.16kN

11. Rivets and bolts subjected to both shear stress ($\tau_{vf,\ cal}$) and axial tensile stress ($\sigma_{tf,\ cal}$) shall be so proportioned that the stresses do not exceed the respective allowable stresses τ_{vf}, and τ_{tf}, and σ if rad the value of $\left(\frac{\tau_{vf,cal}}{\tau_{vf}} + \frac{\sigma_{tf,cal}}{\sigma_{tf}}\right)$ 5does not exceed

(a) 1.0 (b) 1.2

(c) 1.4 (d) 1.8

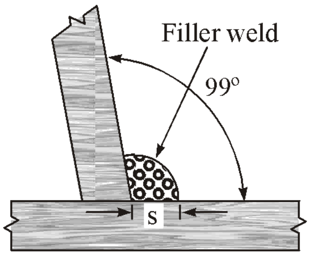
12. A 12 mm thick plate is connected to two 8 mm plates, on either side through a 16 mm diameter power driven field rivet as shown in the figure below. Assuming permissible shear stress as 90 MPa and permissible bearing stress as 270 MPa in the rivet, the rivet value of the joint is



(a) 56.70 kN (b) 43.29 kN

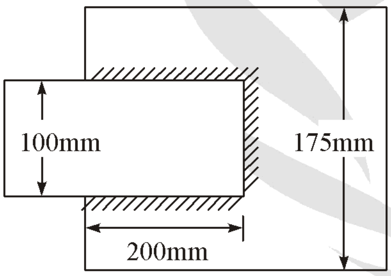
(c) 36.19 kN (d) 21.65 kN

13. For the fillet weld of size 's' shown in the adjoining figure the effective throat thickness is



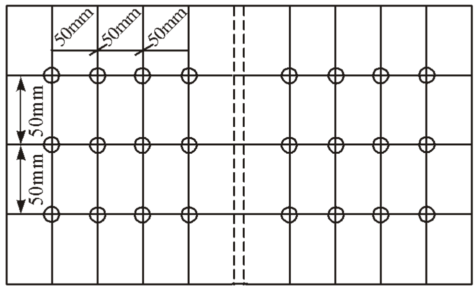
(a) 0.61 s (b) 0.65 s
(c) 0.70 s (d) 0.75 s

14. Two plates, subjected to direct tension, each of 10 mm thickness and having width of 100 mm and 175 mm, respectively are to be fillet welded with an overlap of 200 mm. Given that the permissible weld stress is 110 MPa and the permissible stress in steel is 150 MPa, then length of the weld required using the maximum permissible weld size as per IS : 800-1984 is



(a) 245.3 mm (b) 229.2 mm
(c) 205.5 mm (d) 194.8 mm

15. A double cover butt riveted joint is used to connect two flat plates of 200 mm width and 14mm thickness as shown in the figure. There are twelve power driven rivets of 20mm diameter at a pitch of 50 mm in both directions on either side of the plate. Two cover plates of 10 mm thickness are used. The capacity of the joint in tension considering bearing and shear ONLY, with permissible bearing and shear stresses as 300 MPa and 100 MPa respectively, is

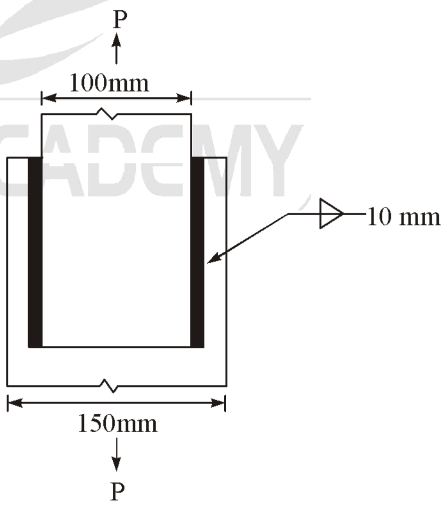


(a) 10863.6 kN (b) 871.32 kN
(c) 541.18 kN (d) 433.7 kN

16. In a steel plate with bolted connections, the rupture of the net section is a mode of failure under

(a) tension (b) compression
(c) flexure (d) shear

17. Two plates are connected by fillet welds of size 10 mm and subjected to tension, as shown in the figure. The thickness of each plate is 12 mm. The yield stress and the ultimate tensile stress of steel are 250 MPa and 410 MPa, respectively. The welding is done in the workshop (γ_{mw} = 1.25). As per the Limit State Method of IS 800:2007. The minimum length (rounded off to the nearest higher multiple of 5mm) of each weld to transmit force P equal to 270 kN is



(a) 100 mm (b) 105 mm
(c) 110 mm (d) 115 mm

18. The conventional flexure theory is not applicable to fasteners when the length to diameter ratio of the fastener is less than

(a) 2.5 (b) 5
(c) 10 (d) 15

19. If the same number of rivets has been used in the joints, then which of the following patterns will yield highest efficiency?

(a) Chain
(b) Staggered
(c) Diamond
(d) All the above yield same efficiency

20. When the load line coincides with the C.G. of the rivet group, then the rivets are subjected to

(a) Only shear
(b) Only tension
(c) Only bending
(d) Both shear and tension

21. Tacking rivets shall have a pitch in line not exceeding

(a) 32t or 300mm whichever is least for plates
(b) 600 mm for compression members
(c) 1000 mm for tension members
(d) All of the above

21. The permissible axial tensile stress in field driven rivets with pneumatic hammer, will be

(a) 100 N/mm^2 (b) 80 N/mm^2
(c) 90 N/mm^2 (d) None of the above

23. A butt weld is specified by

(a) Effective throat thickness
(b) Leg length
(c) Plate thickness
(d) Penetration thickness

24. Permissible shear for a field weld is reduced by

(a) 5% (b) 80%
(c) 15% (d) 20%

25. Design of pins is primarily governed by

(a) Shear (b) Bearing
(c) Flexure (d) All of the above

26. For reversal of stress, the most suited bolt is

(a) Black (b) Turned
(c) Friction grip (d) None of the above

27. High strength bolts are designed on the basis of

(a) Friction (b) Tension
(c) Compression (d) Shear

28. Minimum thickness of steel of the tensile member not exposed directly to weather is

(a) 4 mm (b) 6 mm
(c) 8 mm (d) 10 mm

29. Minimum thickness of steel of the tension members exposed to weather and not accessible for painting is

(a) 4.5 mm (b) 6 mm
(c) 8 mm (d) 10 mm

30. Minimum thickness of secondary steel members not exposed directly to weather is

(a) 4.5 mm (b) 5.0 mm
(c) 6 mm (d) 7 mm

31. Maximum permissible slenderness ratio of steel ties likely to be subjected to compression also is

(a) 250 (b) 350
(c) 450 (d) No limit

32. Allowable tensile stress in mild steel rolled plates up to 20 mm thick is about (in MPa)

(a) 120 (b) 150
(c) 180 (d) 200

33. Allowable tensile stress in high tension steel plate up to 45 mm thick is about in MPa)

(a) 140 (b) 160
(c) 185 (d) 230