UNIT 6 RIVETED AND BOLTED CONNECTIONS AND DETAILING

Structure

6.1 INTRODUCTION

In the earlier unit, you have learned about various shapes of standard structural steel sections manufactured in the steel rolling mills. You have also studied basic components of the structures such as beams and columns. Structures are to be built up by joining the various basic components at different levels. In case a very long member is required in the structural framework, it is sometimes necessary to fabricate the same from the pieces of members of smaller lengths by making proper connections called as ***splice***. One of the earliest methods of connections of different members or splices for making structure as a whole, is by using **rivets** and **bolts**. In many of the old steel bridges crossing over the railway lines, it is observed that the joints are made by rivets and bolts. In case of factories also, connections are required to be made between secondary beams and main beams and a connection of beam to column.

However, nowadays, connections made by welding are more popular due to ease of construction.

Objectives

This unit will help you to understand the purpose of providing rivets and bolts in the construction of steel structures. The material used for construction is mild steel which has a yield strength of 250 N/mm^2 under direct tension.

After studying this unit, you should be able to

- identify the types of rivets/bolts,
- design simple connections using a group of rivets/bolts, and
- draw neat sketches of connection of structural members connected at their ends by rivets/bolts.

6.2 NECESSITY AND FUNCTIONS OF RIVETS/BOLTS

It is a common practice for industrial structures that the floors are made either by chequerred plates or gratings which are supported on ***secondary beams***. The ***secondary beams,*** in turn, are supported on ***main beams*** which are finally supported on ***columns***. The columns are vertical members and are supported near ground level over the top of the R.C.C. pedestal through a suitable connection to the ***base plate*** which is partly embedded in the pedestal.

Generally, when a beam is supported on other beams (or on columns) at both of its ends, the joint is designed to provide a hinged support where only the vertical load is transferred through the connection. However, when a beam acting as a bracket is supported on a column/beam only at one of its ends and the other end remaining free as shown in Figure 6.1 (c), the support is designed as a fixed support where vertical load as well as moment is transferred to the supporting member through the connection.

The rivets or bolts at a joint have to transmit the loads from one member to another member and hence are required to be designed adequately from its strength considerations. Apart from rivets and bolts, additional suitable pieces such as cleat angle (Refer Figure 6.1 (b)), gusset plates (Refer Figure 6.1 (g)) are required to be used for making a proper connection. Figure 6.1 (a) shows a flooring (such as a chequerred plate) resting on a joist. similarly Figure 6.1 (b) shows a joist sitting on the top of another beam. In such cases, the load is said to be transferred through bearing. When a joist is connected to a beam/column by providing a web cleat angle as shown in Figure 6.1 (c) the load is transmitted through shearing action of the rivets. Figure 6.1 (d) shows a splice details of a truss member. The connection is arranged by rivets through a cleat angle (A). Figure 6.1 (e) and (f) show splice details of a beam member and a column member respectively using web splice plate and flange splice plate.

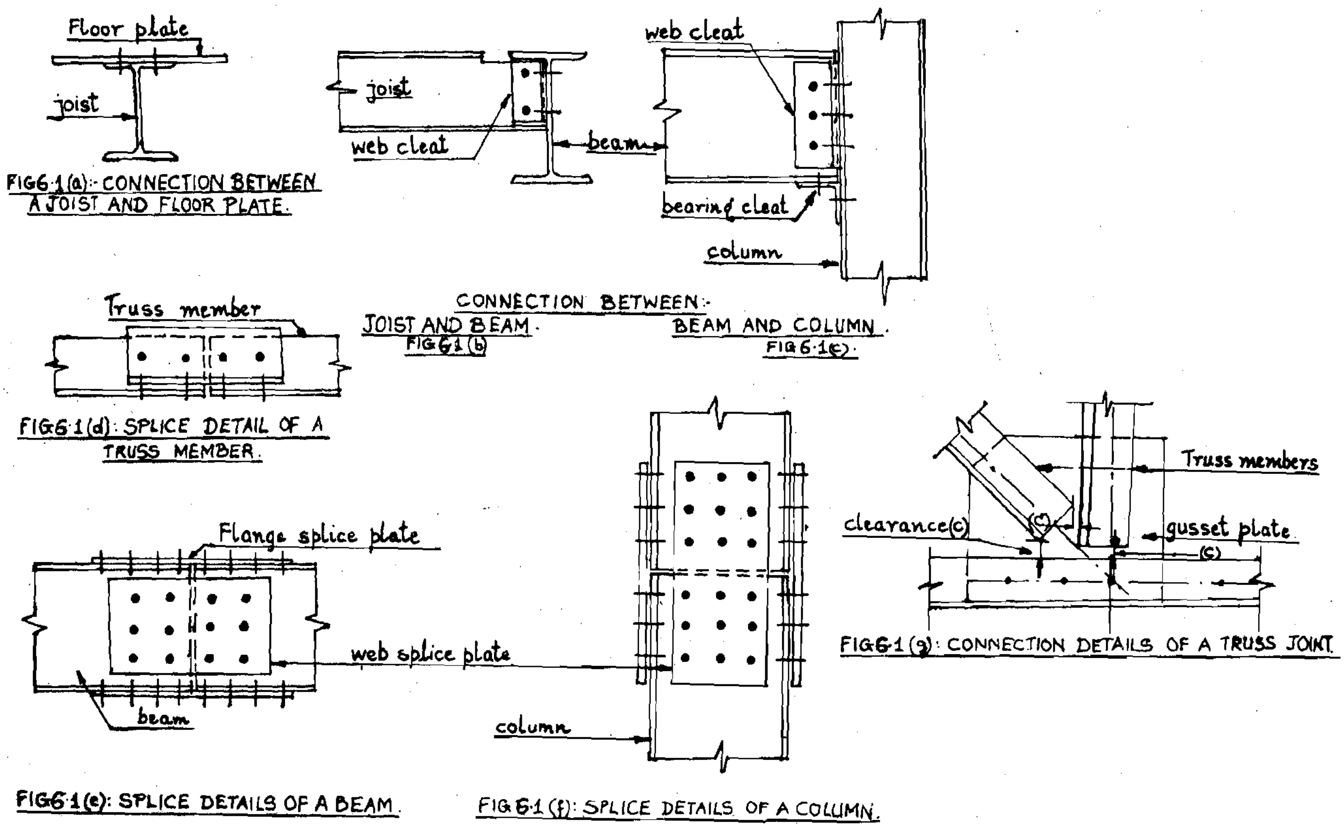


Figure 6.1 : Schematic Details of Typical Joints in a Riveted Structures

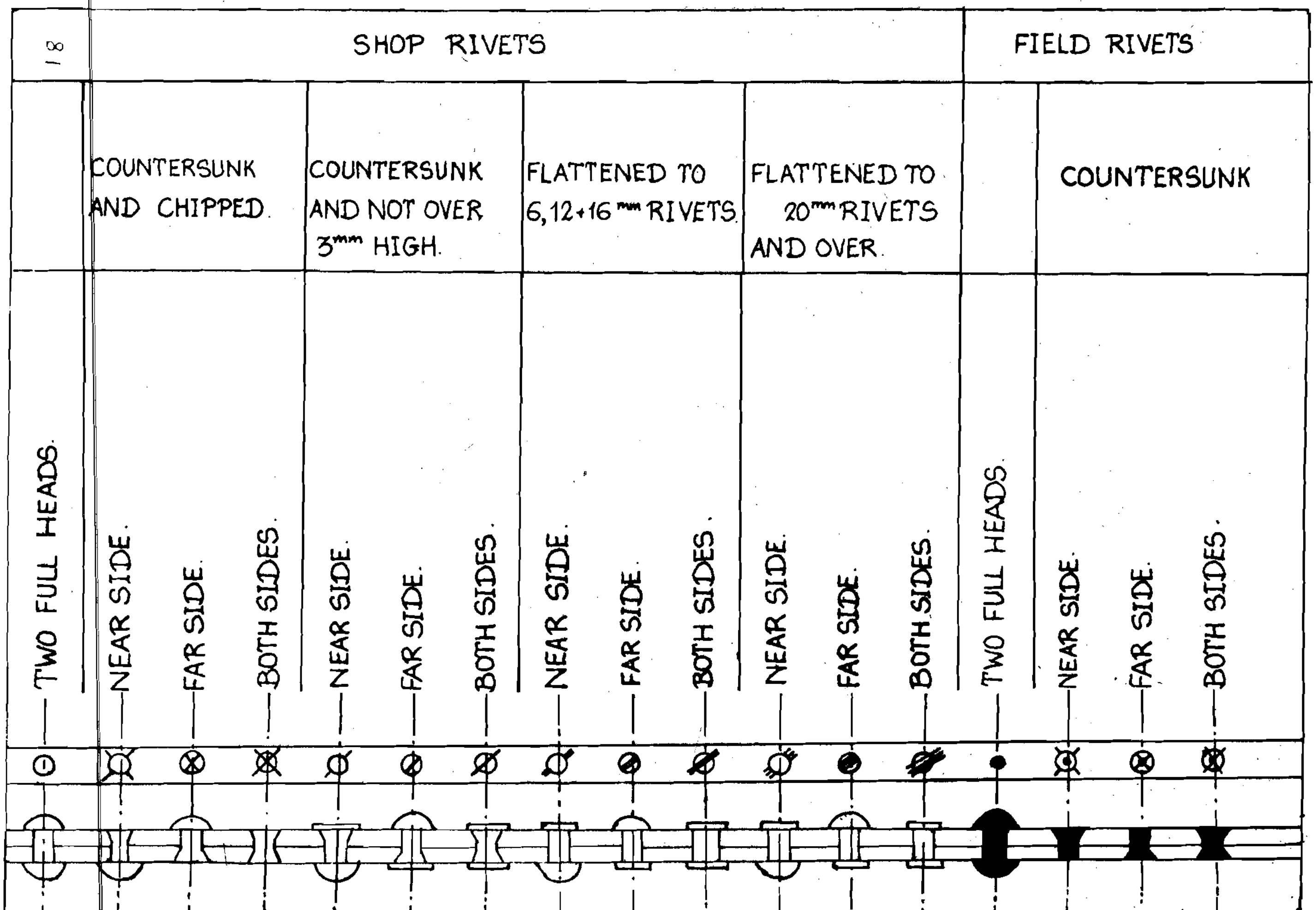
6.3 RIVETS AND BOLTS

6.3.1 Types of Rivets

Even though you may not design riveted structures in normal routine practice except railway bridges and other special structures, rivets being the earliest connectors in steel structures it would be worthwhile to know and understand the basics/use of rivets and their various types. The usual rivet for structural work is shown in Figure 6.2 and has a button-head of approximately hemispherical shape with a diameter of (1.5 D + 3 mm), "D" being the nominal diameter of the shank of the rivet. The height of the head being 0.425 time its diameter which makes it somewhat less than hemispheres. These button heads can be flattened by 6 to 10 mm, partly countersunk for a projection of 3mm or countersunk and chipped flush, based on clearance requirements. It must be noted that rivets countersunk and chipped flush as shown in

Table 6.1 do not ensure development of full strength. Table 6.1 illustrates the standard symbols for various types of rivets on drawings.

Table 6.1 : Types of Rivets



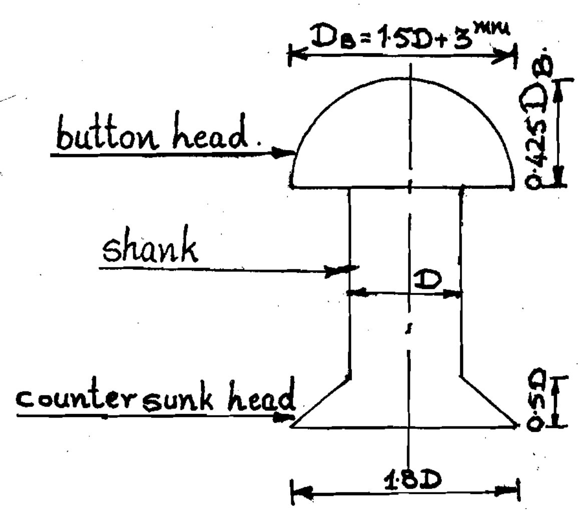


Figure 6.2: Rivet Heads

6.3.2 Sizes of Rivets

The usual size or diameter of structural rivets are 20 mm for industrial buildings/light structures and 22 mm for ordinary bridges and office buildings. For heavy structures, rivets upto 28 mm size may be required and for light trusses, size upto 12 mm rivets may be provided.

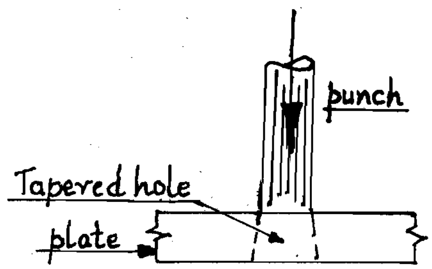


Figure 6.3 : Taper of Rivet Hole

It is desirable to use only one size of rivet in a single member. However, not more than two sizes of rivets should be used, if necessary. As far as the entire structure is concerned, number of different sizes should be small. Nevertheless, to have proper edge distances as given in the structural Engineer's Handbook No.1 of Bureau of Indian Standards, smaller size of rivets have to be used. To keep down costs and wastage, rivets are to be of such length that the part of the shank projecting beyond the face of the structure after the rivet is placed in the hole, will provide just enough metal to form the head after hammering the same.

6.3.3 Fabrication, Punching Hole

Rivet holes may be punched, sub-punched and reamed or drilled. Punched holes are standard, but railway bridge works are often sub-punched and reamed.

The expense of drilling is quite high and hence drilling is adopted for connecting generally the thicker plates as the punching for thicker plates greater than the diameter of the hole is not very satisfactory because of excessive deformation of the surrounding metal. As per Indian Standard IS 800/1984 clause 3.6, diameter of hole upto 25 mm rivet is to be 1.5 mm in excess of its nominal diameter, and for rivets greater than 25 mm, 2 mm in excess be provided unless specified otherwise. For countersunk rivets, additional allowance has to be made.

A punched hole has a noticeable taper, as indicated in Figure 6.4 which increases with the thickness of the plate. This taper aggravates the problem of alignment. Holes cannot be expected to match perfectly in punched work because the action of the punch distorts the metal; hence many of the holes must have reamer passed through them before the rivet can be dropped in.

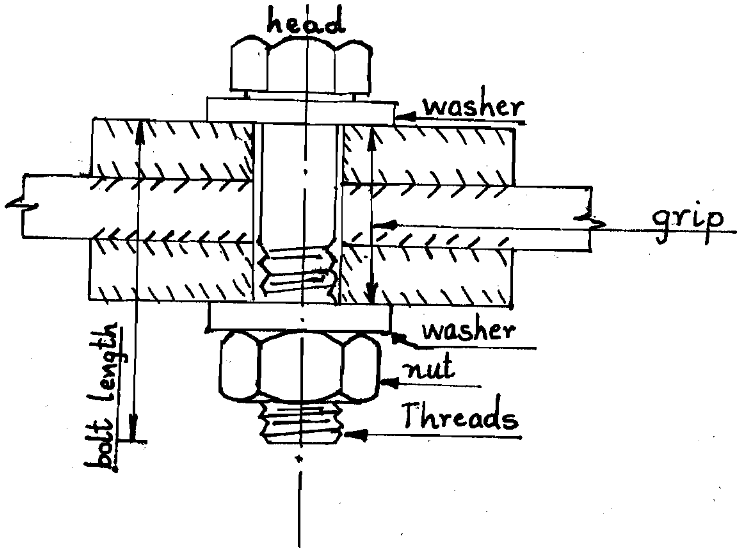


Figure 6.4 : Bolt Assembly

Driving Rivets

The rivet shank with one head already formed is heated until it glows and is inserted in the hole. Then by direct pressure or by a series of blows, a second head is formed before the rivet becomes entirely black. The most satisfactory rivets are produced with direct pressure by use of a power hammer/riveter employing pneumatic, hydraulic or electric power. The riveter grips the rivet between its jaws and produces the head by direct pressure of the order of 500 kN or more. The head is formed by squeezing the rivet. Naturally, the rivet under plastic condition is squeezed out to fill the hole adequately. In joints where rivets are spaced closely or where riveter cannot reach around the member, and also for field connections, the rivet head is usually formed by the pneumatic hammer. No distinction is made in regard to the strength of the rivets made by direct pressure and by the pneumatic hammer, but the former are to be preferred. A hammered rivet may be overdriven which means driven too cold, with the result that its head is not adequately strong.

6.3.4 Bolts

A bolt is a metal pin generally with a hexagonal head formed at one end and the shank threaded at the other end in order to receive a nut. Bolts are used for joining together pieces of metal plates by inserting them through holes in the plates and tightening the nut at the threaded end as shown in Figure 6.4. Structural bolts may be classified according to the following:

a) Type of shank (i) unfinished or (ii) turned.

b) Material and Strength: (i) Ordinary and (ii) High Strength.

c) Shape of head and nut: (i) Square or (ii) Hexagonal.

d) Pitch and fit of thread: (i) standard, (ii) coarse or (iii) fine.

1) Unfinished bolts are forged from rolled steel round rods and have large tolerances on shank and thread dimensions.

2) When tight fit is desired, the bolt holes are reamed or drilled and the bolts are turned or finished to the size necessary for the desired fit.

   In determining the size of bolt holes for bolts less than or equal to 25 mm in diameter, the diameter of the bolt hole shall be assumed to be 1.5 mm in excess of the nominal diameter of the bolt unless specified otherwise. If the diameter of the rivet is greater than 25 mm, the diameter of the hole shall be assumed to be 2.0 mm in excess of the nominal diameter of the bolt unless otherwise specified.

3) Structural Steel for ordinary bolts and high strength bolts shall conform to IS : 1367 and IS : 4000 respectively.

4) Structural bolts usually have hexagonal or sometimes square heads and available in regular and heavy sizes. Hexagonal heads are easier to turn or hold with a wrench and require less turning space. Heavy size nuts may be required for bolts carrying tension loads or when high initial tension is to be developed in bolts by tightening as with high tensile strength bolts.

5) The threaded portion of ordinary and high tensile strength bolts shall have threads as per IS 1364 and IS 1367. Steel washers are usually used under the bolt head and the nut in order to distribute the clamping pressure on the bolted member and also to prevent the threaded portion of the bolt from bearing on the connecting pieces.

6) In order to assume proper functioning of bolted connections under load, the parts must be tightly clamped between the bolt head and the nut. When bolted connections with ordinary bolts are subjected to alternating loads or vibrations, the nuts may become loose and thus reduce the strength of the connection. To prevent this, the nut must be locked in position. A cotter pin with a castallated nuts and a hole drilled in the bolt has been widely used to prevent the nut from further rotation on the bolt beyond its clamped position. Various special nuts such as lock nut or check-nut could be used for the same purpose. Predetermined clamping force can be applied to the bolted assemblies by using calibrated torque-wrenches or by turn or rotation of the nut.

   Anchor bolts are normally embedded in the foundations and they connect foundations to the columns bases and machine frames.

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i) Have you inspected a railway overbridge used for crossing over the railway line and going from one platform to another. What type of members are used in its construction and how are they connected?

ii) Draw a neat sketch of a shear-moment connection between a cantilever bracket from the face of the flange of a column.

iii) What do you understand by the term 'Splice'. Draw a detailing of a column splice assuming the column to be an I-section.

iv) Write a short note on the fabrication aspect of a riveted connection.

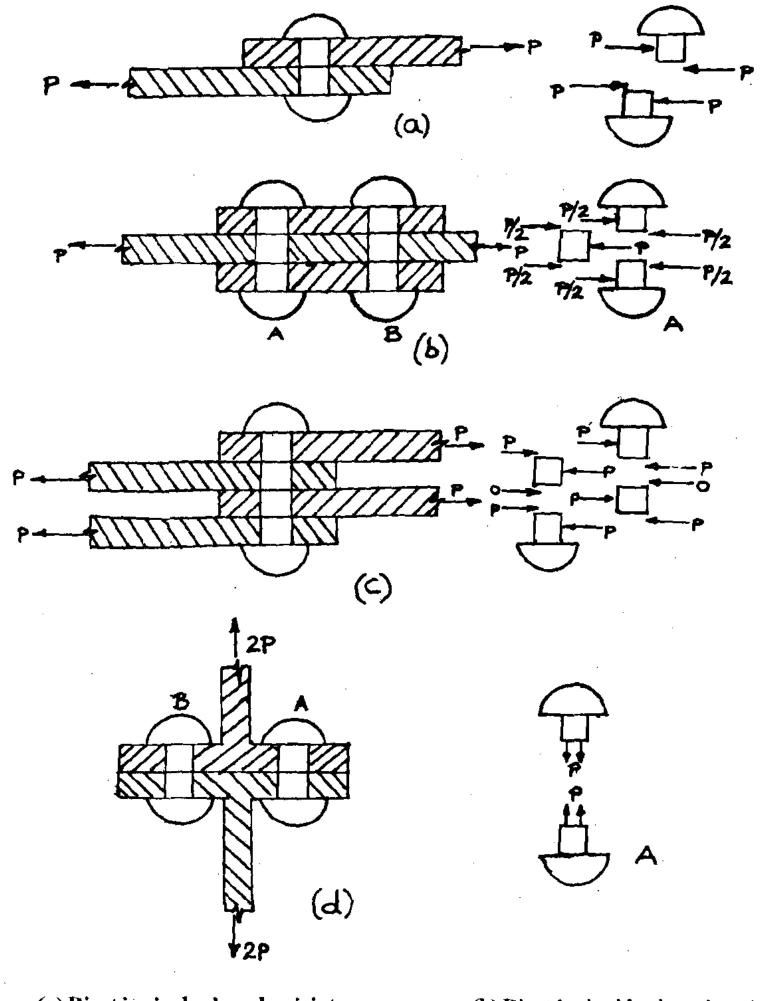
v) a) Draw a neat sketch of a bolted connection connecting two plates, each carrying a tensile force ***T***.

b) Show also a cotter pin through the nut assuming the diameter of the pin to be 3 mm for a bolt size of 25 mm.

6.4 SIMPLE DESIGN OF RIVETED AND BOLTED CONNECTIONS

6.4.1 Types of Connection

Connections can be classified according to the mode of load transmission. Connection loaded as shown in Figure 6.5. (a) (b) & (c) tend to shear the fasteners and are called "shear"



(a) Rivet in single-shear lap joint **(b) Rivet in double-shear butt joint**
(c) Rivet in multiple shear **(d) Rivet in tension**

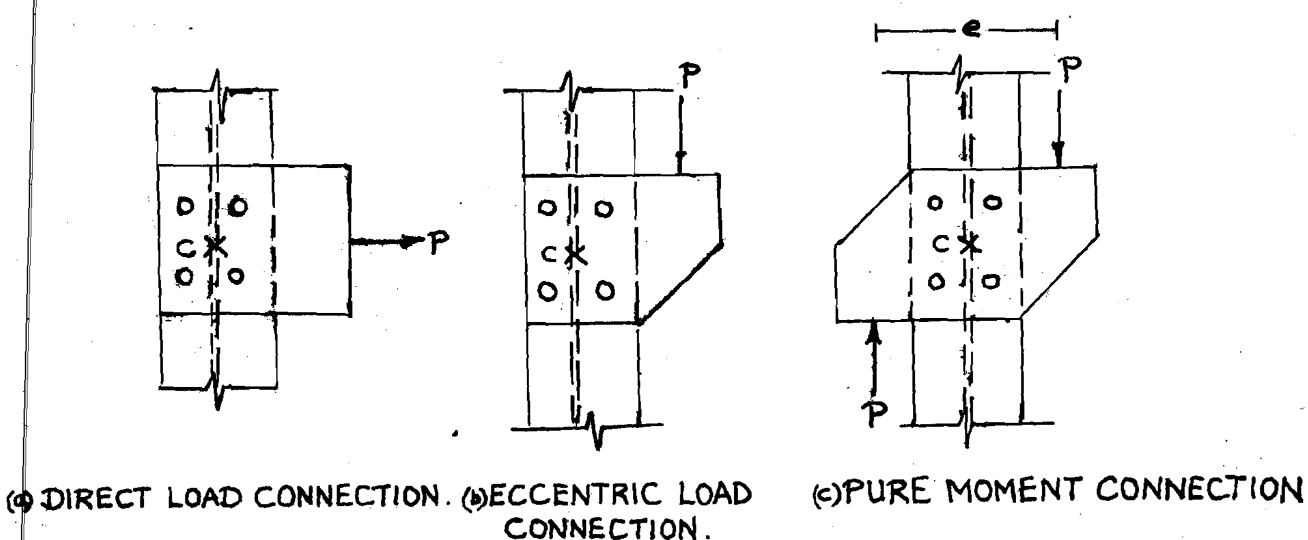
Figure 6.5 : Types of Connections

connections loaded as shown in Figure 6.5. (d) tend to fail the fasteners in tension and are called "tension connections". Figure (6.5) also shows a free body diagram of the rivets in cases (a) to (d) showing the forces acting. If the load in a shear connection is transmitted solely by friction produced by large clamping forces between the plates, the connections is called "friction-type connection", and no slop between the plates can be tolerated. If slip occurs between the plates, and the load is transmitted by bearing between the fasteners and the plates with shear stresses induced in the fasteners, the connection is called "bearing type connection". Ordinarily all riveted connections and those made with common bolts conforming to IS 1963 and 1964 are classified as bearing type connections. The high strength bolts may be used in either friction type or bearing type connections.

A friction type connection is recommended for shear connections subjected to stress reversal, severe stress fluctuations, or in those application where slip would be undesirable. A bearing type connection may be used in application where the load is considered to be essentially static and not vibratory. In friction type connections, the bolt is assumed to bear on the plate with a nominal bearing pressure computed on the basis of uniform stress distribution over an area equal to the nominal bolt diameter times the thickness of the connected plate.

6.4.2 Classification of Connections

Bolted and riveted connections can also be classified according to the nature and location of the load with respect to the fastener group (Figure 6.6).



(a) Direct Load Connection **(b) Electric Load Connection**

(c) Pure Moment Connection

Figure 6.6 : Types of Connections

When the applied load passes through the centroid (c) of the cross-sectional areas of the fastener group, Figure 6.6(a) the connection is said to be carrying direct load. It is also said to be an axially loaded group. However, when the load does not pass through the centroid of the fastener group, it is called as an eccentrically loaded connection Figure 6.6(b). When the load transmitted consists of a pure torque or moment by means of two equal and opposite loads (P) at a distance '*e*' from each other, it is a pure moment connection where torque T = p.e Figure 6.6(c). The beam to column connection carrying moment and shear is called a moment connection along with shear (or shear-moment connection) as shown in Figure 6.1(c).

6.4.3 Indian Standard Code of Practice

i) Indian Standard code of practice for design and general construction is IS 800 : 1984 which incorporates design provision for large grades of mild steel having yield stress from 220 to 540 N/mm^2. However, we will restrict all our calculations to a yield stress of 250 N/mm^2. Students are required to study the various clauses in the code. A few important ones are explained below.

ii) Important design requirements are reproduced from IS 800 below:-

Clause 3.6.1 : Hole Diameter – In calculating the area to be deducted for rivets, bolts or pins, the diameter of the hole shall be taken.

Clause 3.6.1.1: In making deduction for rivets less than or equal to 25 mm in diameter, the diameter of the hole shall be assumed to be 1.5 mm in excess of the nominal diameter of the rivet unless specified otherwise.

If the diameter of the rivet is greater than 25 mm, the diameter of the hole shall be assumed to be 2.0 mm in excess of the nominal diameter of the rivet unless specified otherwise.

Clause 3.6.1.2: In making deduction for bolts, the diameter of the hole shall be assumed to be 1.5 mm in excess of the nominal diameter of the bolt, unless otherwise specified.

Clause 3.6.1.3: For countersunk rivets or bolts, the appropriate addition shall be made to the diameter of the hole.

Clause 3.6.2.4: The areas to be deducted shall be the sum of the sectional area of the maximum number of holes in any cross-section at right angles to the direction of stress in the member for all axially loaded tension member (except as indicated in Clause 3.6.2.2. as depicted in Figure 6.7).

In the case of rivets placed in staggered fashion as shown in Figure (6.7) the deduction for rivet holes = sum of sectional areas of holes B, C and D

$$\left\{\frac{S_1^2\, t}{4g_1} + \frac{S_2^2\, t}{4g_2}\right\}$$

Clause 3.9.2.1 (b): Increased stresses in rivets, bolts and tension rods : When the effect of the wind or earthquake load is taken into account, the permissible stresses specified may be exceeded by 25 percent (Clause 3.9.4: Where the wind load is the main load acting on the structure no increase in the permissible stresses is allowed).

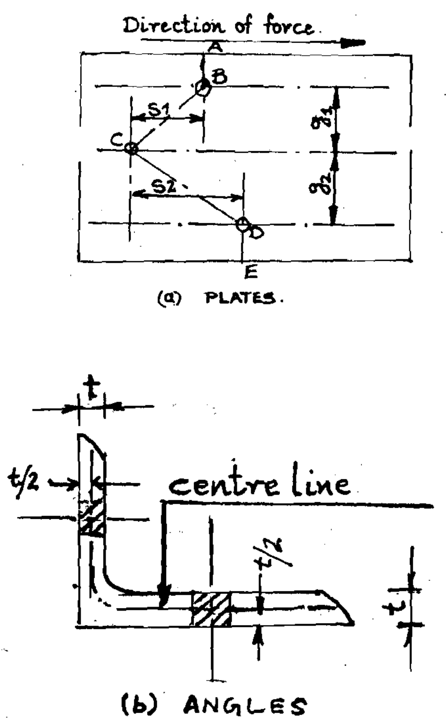


Figure 6.7 : Staggered Pitch, Steel Gauge (IS 800 : Cl : 3.6.2.2)

Clause 3.9.2.2. Erection Load: Allowable stresses in rivets and bolts may be increased by 25 % when secondary effects are considered with or without wind/earthquake loads.

iii) Stresses in rivets and bolts (Clause 8.9.4.1 Table 6.2).

Table 6.2 : Maximum Permissible Stress in Rivets and Bolts

Description of Fasteners (f)	Axial tension σ_{tf} (MPa)	Shear τ_{vf} (MPa)	Bearing σ_{pf} (MPa)
Power-driven rivets	100	100	300
Hand-driven rivets	80	80	250
Close tolerance and turned bolts	120	100	300
Bolts in clearance holes	120	80	250

Clause 8.9.4.2 : The permissible stress in a high tensile steel rivet shall be those given in Table 6.2 multiplied by the ratio of tensile strength of the rivet material to the tensile stress as per IS 1148-1982.

Note : For field rivets, the permissible stresses shall be reduced by 10%.

Clause 8.9.4.3 : The permissible stress in a bolt (other than high strength friction grip bolt) of class higher than 4.6 shall be those given in Table 6.2 multiplied by the ratio of its yield stress or 0.2 per cent proof stress or 0.7 times its tensile strength whichever is the lesser, to 235 MPa.

Clause 8.9.4.4 : The calculated bearing stress of a rivet or bolt on the parts connected by it shall not exceed (a) the value f_y for hand driven rivets or bolts in clearance hole and (b) the value $1.2.f_y$ for power driven rivets or close tolerance and turned bolts where f_y is the yield stress of the connected parts.

Where the end distance of a rivet or bolt (that is, the edge distance in the direction in which it bears) is less than a limit of twice the effective diameter of the rivet or bolt, the permissible bearing stress of that rivet or bolt on the connected part shall be reduced in the ratio of the actual end distance to that limit.

Clause 8.9.4.5 : Rivets and bolts subject to both shear and axial tension shall be so proportioned that,

$$\frac{\tau_{vf,Cal}}{\tau_{\tau\phi}} + \frac{\sigma_{tf,Cal}}{\sigma_{tf}} \ngtr 1.4$$

Clause 8.9.4.6 : Provisions in clause 8.9.4.1 to 8.9.4.5 are not applicable to high strength friction grip bolts for which IS 4000-1967 is to be referred.

Clause 8.10.1 : Pitch of rivets (and bolts).

a) **Minimum pitch**

The distance between centres of rivets should be not less than 2.5 times the nominal diameter of the rivet.

b) **Maximum Pitch**

i) The distance between centres of any two adjacent rivets (including tacking rivets) shall not exceed $32t$ or 300mm, whichever is less, where 't' is the thickness of the thinner outside plate.

ii) The distance between centres of two adjacent rivets, in a line lying in the direction of stress, shall not exceed 16 t or 200 mm, whichever is less, in tension members and 12 t or 200 mm, whichever is less, in compression members. In the case of compression members in which forces are transferred through butting faces, this distance shall not exceed 4.5 times the diameter of the rivets for a distance from the abutting faces equal to 1.5 times the width of the member.

iii) The distance between centres of any two consecutive rivets in a line adjacent and parallel to an edge of an outside plate shall not exceed (100 mm + $4t$) or 200 mm, whichever is less in compression or tension members.

Figure 6.8 (a) refers to clause 8.10.1, part (a) and Figure 6.8 (b) (i), b (ii) and b (iii) refer to clause 8.10.1, parts b (i) to b (iii).

iv) When rivets are staggered at equal intervals and the gauge does not exceed 75 mm, the distance specified in (ii) and (iii) between centres of rivets, may be increased by 50 per cent.

Clause 8.10.2 : Mininum Edge distance from centre of hole is given the following Table 6.3.

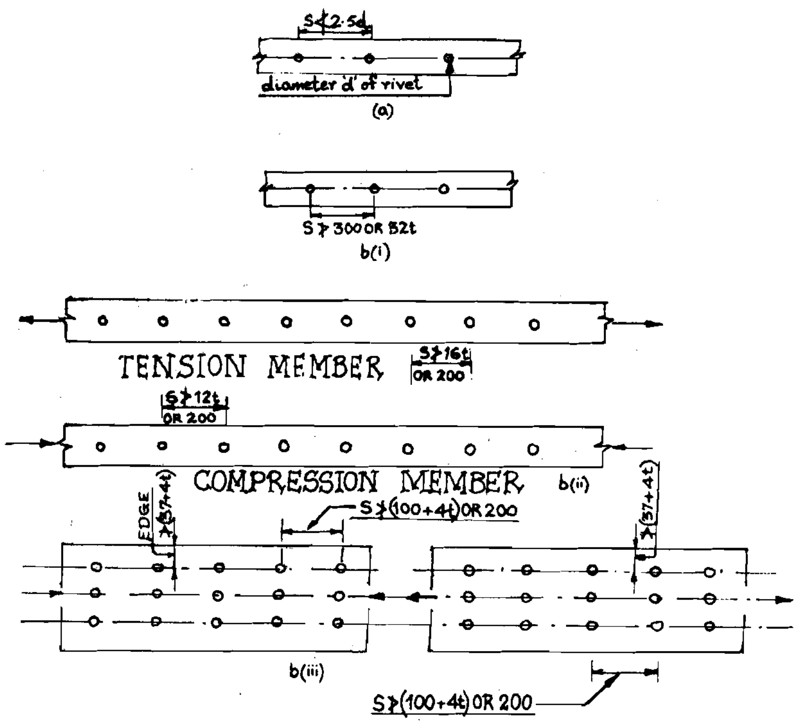


Figure 6.8 : Pitch of the Rivets/Bolts

Table 6.3

Diameter of Hole (in mm)	Distance to sheared or hand flame cut edge (in mm)	Distance to rolled, machine flame cut, sawn or planed edge (in 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

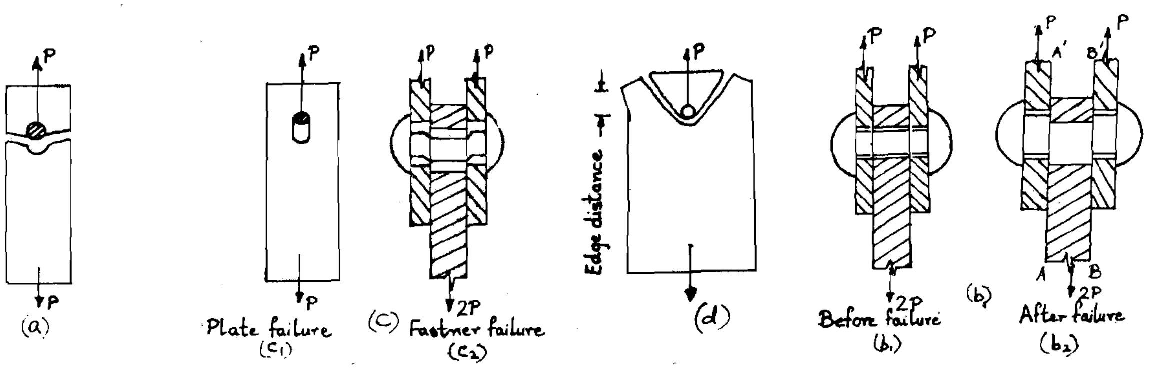
6.4.4 Types of Failures of Riveted Connections

Figure 6.9 shows various types of failures of riveted connection under axial tension. Part (a) of the figure shows the failure of the plate where the crack is passing through the rivet hole. This is possible when the edge distance beyond the rivet hole is quite small. In view of this, IS code has recommended the minimum edge distances as specified in Clause 8.10.2.

Part (b2) of Figure 6.9 indicates the failure of the rivet in shear. In this case, the joint has double cover plate and hence the failure is in double shear along planes A-A′ and B-B′

Part (c) of the Figure 6.9 is a typical failure under heavy bearing pressure. The failure may occur, either in the plate as shown in part (c1) or in the fastener (i.e. the rivet) as shown in part (c2) due to the over stress under bearing.

Part (d) shows the shear-out failure of the plate near its end. This failure is due to cracking of the plate through the last rivet as shown due to low value of edge distance.



(a) Tension failure in the plates
(b) Shearing failure in the fastener
(c) Bearing failure
(d) Shear-out failure in the plate
Figure 6.9 (a) : Types of Connection Failures

6.4.5 Stresses in Rivets

The values of permissible stresses in rivets/bolts are given in Table 6.2.

The tensile stress in the section is given by

$$\sigma_{at,cal} = \frac{P}{A_n}$$

where P is the load, and , A_n is the net sectional area of the member connected and is equal to the gross section A_g less deductions for all holes $\left(\sum D_H \times t\right) D_H$ being the diameter of the hole. $A_n = A_g - \sum D_H t$

As long as the calculated tensile stress in the member given by

$$\sigma_{at,cal} = \left(\frac{P}{A_g - \Sigma D_H \times t}\right)$$

does not exceed the permissible value of tensile stress, the failure in the member is not possible. However, the failure at the joint is to be checked as per Section 6.5.4.

The shear stress in the fasteners is given by

$$= T_{vf,(cal)} = \frac{P}{A_f}, \text{ where}$$

i) P is the load, and

ii) A_f is the total shearing area of fasteners $\left(\frac{\Sigma \pi D^2}{4}\right)$, where D is gross diameter or diameter of the hole for the rivet and shank- diameter for the bolt. Shear failure of the fastener is avoided it,

$T_{vf\,(cal)} \leq T_{vf\,(permissible)}$

iii) The unit bearing stress between the fasteners and the connected member is given by

$$\sigma_{pf,cal} = \frac{P}{nDT}$$

where,

i) P is the applied load

ii) n is the number of rivets along the line of rivet,

iii) D is the gross diameter of the rivet or shank diameter of the bolt

iv) t is the thickness of each cover plate or half the thickness of main plate, whichever is smaller.

6.4.6 Special Features, and Distinction Between Rivets and Bolts

The type of connections made by using rivets or bolts are similar from functional point of view. Hence the general discussions of the group of rivets related with their classifications strength, etc. can also be applied to bolted connections. However, there are following advantages and disadvantages of riveted and bolted connections:

1) After the rivet is hammered in a particular hole, the cross-sectional area of the rivet is the full area of the hole as the rivet fills the hole completely. Hence the shear strength of the rivet is computed by considering its gross diameter which is equal to the diameter of the hole. The bearing strength of the rivet is also based on the diameter of the hole. However in the case of bolted connections, the diameter of the shank remains unchanged even after the connection is made. Hence, the strength of the bolt is based on its original shank diameter.

2) The riveted connection can be used for making the joints of boiler shells since the joints are made water-tight. A bolted connection cannot be guaranteed to make a water-tight or leak- proof connection. Since there is always a clearance between the shank and the hole in the plate.

3) There is a special advantage in the case of bolted connections that the bolts can be easily removed and any defective member can be replaced and bolted back. This type of dismantling of the structures and again making the joints after correcting the member is not easily feasible with riveted connections.

6.5 INSPECTION AND TESTING

Indian standard code of practice for general construction in steel (IS 800-1984) has made certain provisions regarding inspection and testing. The relevant clauses under 11.13 of the code are reproduced below:

1) The inspector shall have free access at all reasonable times to those parts of the manufacturer's works which are concerned with the fabrication of the steel work and shall be afforded all reasonable facilities for satisfying himself that the fabrication is being undertaken in accordance with the provision of this standard.

2) Unless specified otherwise, inspection shall be made at the place of manufacturer prior to despatch and shall be conducted so as not to interfere unnecessary with the operation of the work.

3) The manufacturer shall guarantee compliance with the provisions of this standard, if required to do so by the purchaser.

4) Should any structure or part or a structure be found not to comply with any of the provisions of this standard, it shall be liable to rejection. No structure or part of the structure, once rejected shall be resubmitted for text. except in cases where the purchaser or his authorised representative considers the defect as rectifiable.

5) Defects which may appear during fabrication shall be made good with the consent of and according to the procedure laid down by the inspector.

6) All gauges and templates necessary to satisfy the inspector shall be supplied by the manufacturer. The inspector, may, at his discretion, check the test results obtained at the manufacturer's works by independent tests at the Government Test House or elsewhere and should the material so tested be found to be unsatisfactory, the cost of such tests shall be borne by the manufacturer, and if satisfactory, the cost shall be borne by the purchaser.

Example 6.1

A double-riveted double-cover butt joint (Refer Figure 6.11) in plates 16 mm thick is made for a boiler shell with 25 mm rivets at 100mm pitch. If the value of maximum allowable permissible axial tensile strength for plate is 160N/mm^2, shear and bearing on rivets are ($\tau_v = 80$ N/mm^2 and $\sigma_{br} = 250$ N / mm^2 respectively calculate the maximum pull per pitch length that can be applied. Compute also its efficiency.

Solution

Considering the various strengths of the joint per pitch length of 100 mm, d = 25 mm, D = 26.5mm, t = 16 mm as shown in Figure 6.10.

We have

1) Capacity of plate in tension = $\sigma_{at} \times (100 - 26.5)\ 16$

$$T = \frac{160 \times 73.5 \times 16}{1000} = 188.2 \text{ kN.}$$

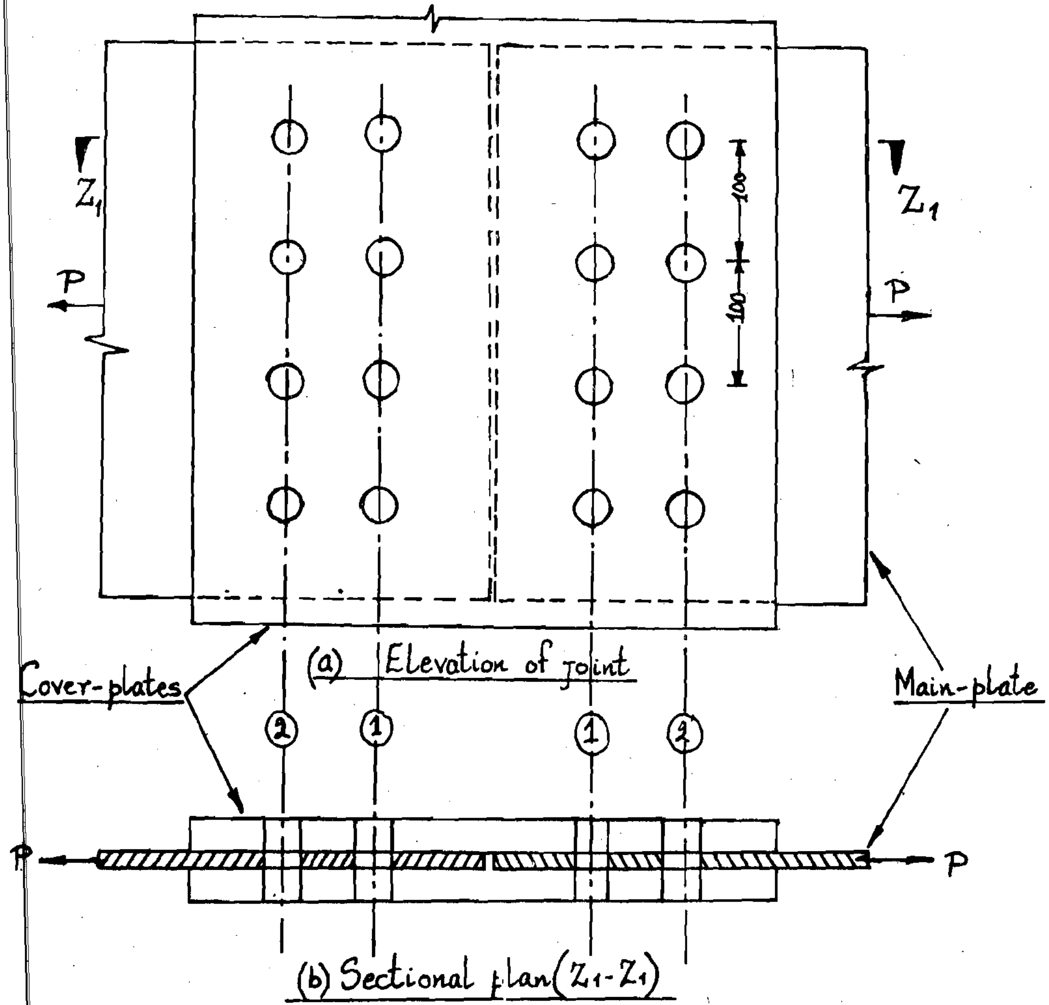


Figure 6.10 : Details of Vertical Joint on Part of Boiler Shell

2) Shear capacity of rivets with 2 nos and failure under double shear,

$$Q = \frac{2 \times 2 \times \frac{\pi}{4} \times (26.5)^2 \times 80}{1000} = 176.4 \text{ kN.}$$

3) Bearing capacity of rivets,

$$P_B = 2 \times d \times t \times (\sigma_{br}) = \frac{2 \times 25 \times 16 \times 250}{1000} = 176.4 \text{ kN.}$$

4) Strength of solid plate,

$$P_p = \frac{100 \times 16 \times 160}{1000} = 256 \text{ kN.}$$

The rivets in double shear have the lowest load capacity and hence maximum safe load of 176.4 kN can be applied.

The efficiency of the joint is $\frac{176.4}{256} = 68.9\%$.

Example 6.2

Figure 6.11 (a) shows a staggered riveted group subjected to axial load P_1,
Figure 6.11 (b) shows a riveted group having rivets in four straight rows and subjected to axial load P_2. Assume diameter of rivets = 25 mm, thickness of plates = 16 mm
Determine the safe loads, P_1 and P_2 for the two cases and comment on the results.

Solution

Assume permissible tensile stress = 150 N/mm²

Case (a) : Area of Cross -section of valid plate = 240 × 16 = 3840 mm².

Along section ABCDE, there are three rivet holes, for portion BC & CD; S =70 mm and g = 70 mm as shown in Figure 6.11 (a).

Reduction of holes = Area of 3 rivet holes $- \sum \frac{S^2 t}{4g}$

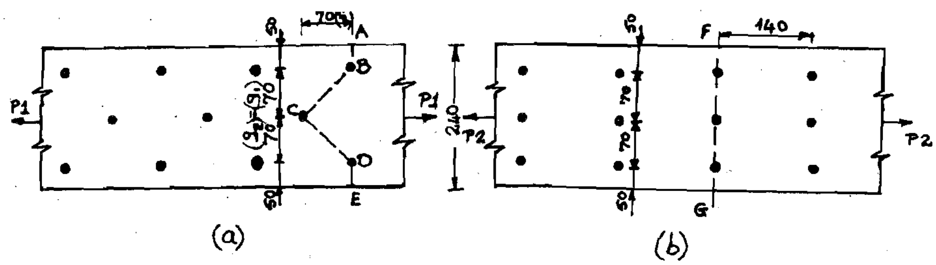


Figure 6.11

$$= 3 \times 26.5 \times 16 - 2\left\{\frac{(70)^2 \times 16}{4 \times 70}\right\}$$

$$= 1272 - 560 = 712 \text{ mm}^2$$

Net area of section = 3840 – 712 =3128 mm²

$$\therefore \quad P_1 = \frac{150 \times 3128}{1000} = 469.2 \text{ kN.}$$

Case (b) : All rivets are in one line

$$\therefore \; S = 0$$

∴Net area of plate = 3840 – 127 = 2568 mm²

$$\therefore \quad P_2 = \frac{150 \times 2568}{1000} = 385.2 \text{ kN.}$$

Comment : It is therefore observed that staggering of rivets/bolts is advantageous when a member is under axial tension.

Example 6.3

a) Determine the "rivet value" of a 16 mm diameter rivet connecting a main plate of 12 mm to two cover plates, each of 8 mm thickness as shown in Figure 6.12. Assume $\sigma_{at} = 150 \text{ N/mm}^2$, $T_{vf} = 100 \text{ N/mm}^2$, $\sigma_{pf} = 300 \text{ N/mm}^2$

b) Determine the same for bolted connection with sizes same as above.

Solution

a) d = 16 mm; D_H = 17.5 mm

For riveted connection, the rivet fills up the hole completely and gross-area of cross-section of rivet is available for its strength. Since there are two planes of failure under shear

$$\text{Shear strength} = 2 \,.\, \frac{\pi}{2}(17.5)^2 \,.\, \frac{100}{1000} = 48.1 \text{ kN} \qquad \ldots \text{(I)}$$

As far as bearing is considered, there are two possibilities of bearing failure

i) in main plate

ii) in cover plate

i) Main plate

$$P_{b1} = 17.5 \times 12 \times \frac{300}{1000} = 63 \text{ kN} \quad \ldots \text{(II)}$$

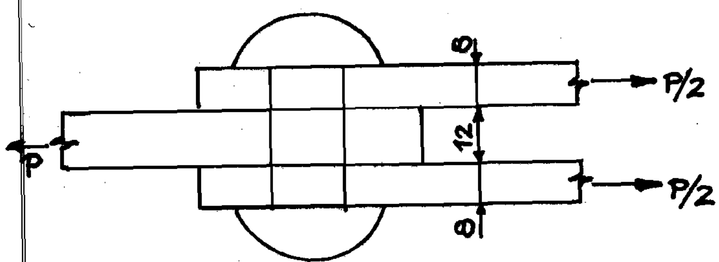


Figure 6.12

ii) Two cover plates of ($2 \times 8 = 16$ mm) thickness carry a total load (P)

$$P_{b2} = 17.5 \times 16 \times \frac{300}{1000} = 84 \text{ kN} \quad \ldots \text{(III)}$$

Thus critical value of rivet under bearing is 63 KN out of (II) and (III)

Rivet value is the least of all the strengths and in this case it is = 48.1 KN, the shear strength of the rivet.

b) $d = 16$ mm, $D_H = 17.5$ mm

$$\text{Area of cross-section of bolt } A_b = \left(\frac{\pi}{4} d^2\right) = 201 \text{ mm}^2$$

$$Q = \text{Double shear strength of bolt} = \frac{2 \times 201 \times 100}{1000} = 40.2 \text{ kN}$$

For two 8 mm plate = $2 \times 16 \times 8 = 256$ mm^2 and for 12 mm plate = $16 \times 12 =$ 192 mm^2

$$\text{Shearing value} = \frac{300 \times 192}{1000} = 57.6 \text{ kN}$$

Thus design bolt value of 16 mm dia bolt is 40.2kN.

Example 6.4

Design the member and gusset plate connection for a tension member of a truss to carry an axial tension of 80 kN (Figure 6.13).

Solution

Assume permissible tensile stress = 150 N/mm^2

Area required = 80/0.15 = 533 mm^2

Try an angle section $65 \times 65 \times 6$ with rivets of of 16 mm diameter, D_H = 17.5 mm as shown in Figure 6.14 (a).

A_1 = Area of connected leg = (65 –17.5) 6 = 285 mm^2

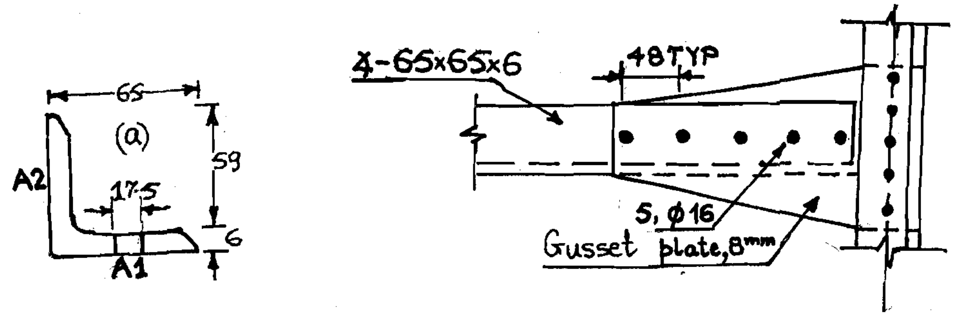
A_2 = Area of outstand (i.e. other leg)$_1$ = $59 \times 6 = 354$ mm^2

Referring IS 800 – 1984, under clasue 4.7 on page 37,

$$\therefore \quad \text{Net area} = (A_1 + A_2 K)$$

where,

$$K = \frac{3 A_1}{3 A_1 + A_2} = 0.72$$



(a) (b)

Figure 6.13

$$\therefore \quad A_1 + A_2 k = 285 + 0.72 \times 354 = 540 \text{ mm}^2 > 533 \text{ mm}^2$$

End connection of the member with Gusset plate 8 mm thick is shown in Figure 6.14 b

Strength in single shear = $\sigma_{pf} \times d \times t = \dfrac{250 \times 17.5 \times 6}{1000} = 26.25$ kN

Strength in single shear = $\tau_{vf} \times \dfrac{\pi}{4}(D_H)^2 = \dfrac{80 \times 201}{1000} = 19.2$ kN

Number of rivets $= \dfrac{80}{19.2} = 4.15$ (say 5 Nos.)

Example 6.5

A compound beam is formed of I section and plates on top and bottom flanges as shown in Figure 6.14 (a), (b)

Design the rivet connecting the flange plate (200 × 10) to the I section ISMB - 300 for given data:

$$I_{xx} = 18216.0 \text{ cm}^4$$

Shear Force at A = 150 kN

Permissible stresses are as under

$\sigma_{at} = 150$ N / mm^2 (Tensile)

$T_{vf} = 100$ N / mm^2 (shear)

$\sigma_{pf} = 300$ N / mm^2 (bearing)

Solution

Try 20 ϕ rivet $d = 20$ mm ; $D_H = 21.5$ mm

Single shear value = $100 \times \dfrac{\pi}{4} \times \dfrac{(21.5)^2}{100} = 36.3$ kN

Bearing value = $\dfrac{300 \times 12 \times 21.5}{1000} = 77.4$ kN

n = number of rows of rivets connecting the cover plate with the flange (= 2 rows)

S = shear per mm

P = pitch of rivets in mm

r = safe resistance of rivet = 36.3 kN

P = pitch of rivets in mm

$$n \times r = s \times p \quad p = n \times \frac{r}{s}$$

Also $s = \dfrac{SA\bar{Y}}{I}$ where,

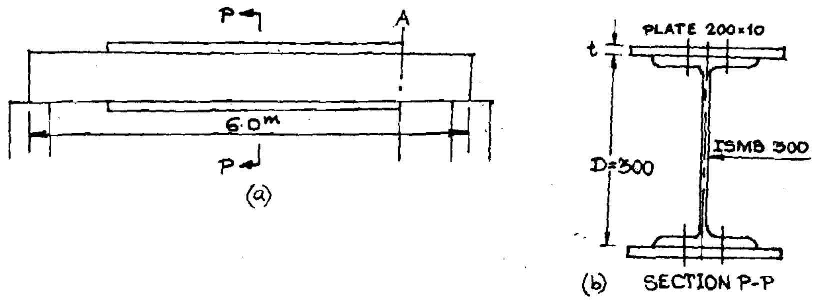


Figure 6.14

1) S = shear force

2) A = Net area of flange plate (shown shaded) to be connected = 2000 mm^2 – rivet hole

3) $\bar{Y}$= centroidal distance of 'A' from neutral axis = $\frac{D}{2} \times \frac{t}{2}$ = 155 mm

Assume, A = 2000 mm^2;

I = 18216.9 cm^4 without deduction for holes.

$$\therefore \quad S = \frac{150 \times 2000 \times 155}{18216.9} \times 10^{-4} = 0.255 \text{ kN / mm}$$

$$\therefore \quad p = \frac{n \times r}{s} = \frac{2 \times 36.3 \times (kN)}{0.255 \text{ (kN / mm)}} = 284.7 \text{ mm C/c}$$

Since thickness of top/bottom plate = 10 mm.

As per IS 800 – clause 8.10.b (ii) Spacing (P) $\not>$ 12 × 10 = 120 mm

Provide 20 ϕ rivets @ 120 c/c staggered on either side of the web on each flange, where one hole will be deducted from the area of the plate,

∴ connected area of plate = 2000 -21.5 x 10 = 1785 mm^2

Note : The revised or connected value of pitch P can be calculated again by substitute (i) A = 1785 mm^2 (ii) value of the I for beam and plates considering the holes.

Figure (6.14- a, b) show elevation (a) and sectional plant (b) of a built up column

Example 6.6

ISMC 200 provided @ 250 mm c/c designed to carry a compression load of 300 kN and the two legs are attended by 250 × 10 mm plates at 1000 c/c. Design the connecting bolts of 20 mm diameter.

Solution

The battens are to be designed for transverse shear 'V' of 2.5% of total axial force as per clause 5.8.2.1 (I.S. 800) and also resist simultaneously a longitudinal shear,

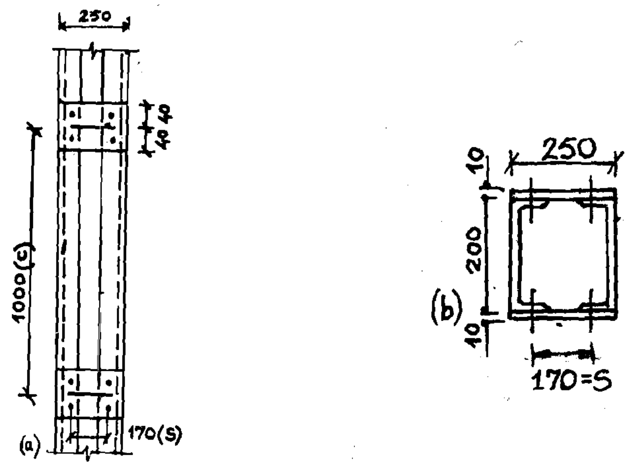
$$V_1 = \frac{VC}{2N} \text{ and moment, } M = \frac{VC}{2N}$$

$$\text{In the example, } V = \frac{2.5}{100} \times 300 = 7.5 \text{ kN (transverse)}$$

$$C = 1000 \text{ mm}, \ N = 2, \ S = 170 \text{ mm}$$

$$\therefore \quad V_1 = \frac{7.5 \times 1000}{2 \times 170} = 22.06 \text{ kN (transverse)}$$

$$\therefore \quad M = \frac{7.5 \times 1000}{2 \times 2} = 1785 \text{ kN/mm}$$



(a) (b)

Figure 6.15

This moment produces a horizontal shear force in bolts equal to (1875/80) = 23.4 kN resultant shear in each bolt

$$= \sqrt{(22.06)^2 + (23.4)^2} = 33.2 \text{ kN}$$

Assuming T_{vf} = 100 N/mm² (shear) and

$$\sigma_{\pi\phi} = 300 \text{ N/mm}^2 \text{ (bearing)}$$

$$\text{Rivet capacity in shear} = \frac{100 \times \frac{\pi}{4} \times (20)^2}{1000} = 31.4 \text{ kN}$$

$$\text{and in bearing} = \frac{300 \times 20 \times 10}{1000} = 60 \text{ kN}$$

As rivet value of 31.4 kN is only 2.5% lower than 32.2 kN, we may accept them. Otherwise, we may reduce 'C' from 1000 mm to 950 mm to get a rivet force of

$$\left(\frac{950}{1000} \times 32.2\right) = 30.6 \text{ kN} < 31.4 \text{ kN}$$

A double riveted lap joint for a 16 mm thick plate is made by using 25 mm diameter rivets at 100 mm c/c. Assuming the maximum permissible axial tensile strength as 16 N/mm² for plates, 80 N/mm² and 250 N/mm² for rivets in shear and bearing respectively. Determine the maximum force that can be applied per pitch length. Determine also the efficiency of the joint.

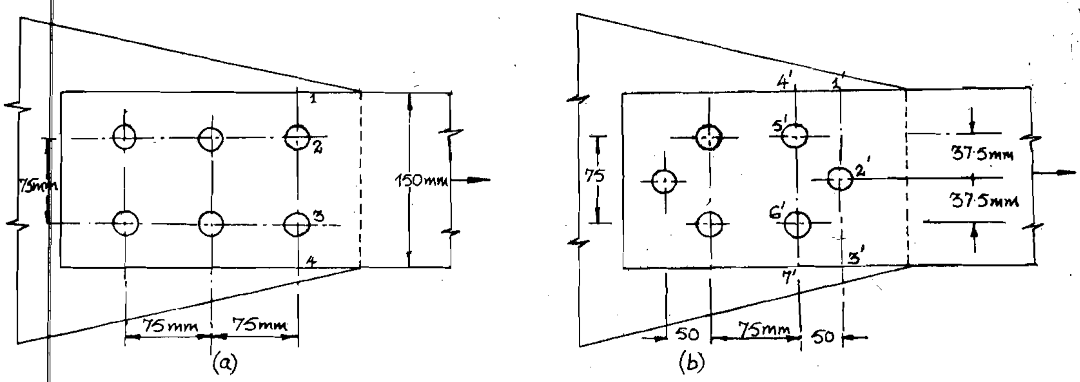
Note: The solution is on the same lines as solved in Example No.1.

SAQ 2

i) A flat of size 15 × 1.2 cm is used as a tension member. It can be connected to gusset plate by the two alternate methods of riveting shown in Figure 6.16(a) (b). Calculate the maximum tension that the flat can carry in both case if the diameter of rivets is 22 mm and the permissible tensile stress in the flat is 150 mpa.

ii) Calculate the strength of ISA 40 × 25, 6 mm thick as shown in Figure 6.17, when used as a tension member with its longer leg connected by 14 mm diameter rivets.

iii) Using the data of solved example No.4 try a tension member consisting of two angles 50 × 50 × 65. If this member is inadequate, check whether two angles of 50 × 50 × 8 is satisfactory.



(a) (b)

Figure 6.16

Assume the permissible stresses as follows:

1) Tensile stress for angle section = 150 N/mm^2

2) Shear stress for rivet = 80 N/mm^2

3) Bearing stress for rivet = 250 N/mm^2

iv) Using the data of solved example No.5 try a 16 mm rivet and indicate whether it is safe for a spacing of 120 mm c/c.

v) If the thickness of the plate is 20 mm instead of 10 mm and other data remaining same as given in solved example No. 5, determine the spacing of rivets for following two diameters

a) 16 mm, b) 20 mm

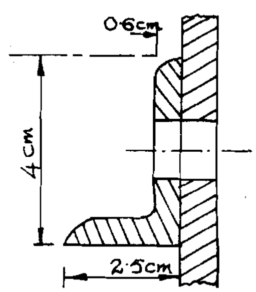


Figure 6.17

6.6 SUMMARY

In this unit you have been given a brief idea about rivets and bolts in respect of the following items

i) Necessity and function of rivets

ii) Types of rivets and bolts

iii) Group of rivets/bolts forming a joint

iv) Strength of a joint.

v) Simple design procedure of a joint

vi) Various provisions in relevant IS code of practice.

More emphasis is laid in drawing figures of various details of connections. This is going to be useful when you study unit No. 8 of detailing of structures where detailing of joints is quite important. From this point of view, students should pay more attention in practising of drawing the various sketches of joints neatly as illustrated in various figure.

6.7 ANSWERS TO SAQs

SAQ 1

Refer corresponding proceeding text for Answers of all SAQs.

SAQ 2

i) Maximum tension in the flat = 185.4 kN for case (a) maximum tension in the flat = 203.1 kN for case (b).

ii) Strength of the member = 34.05 kN.

Solution of problems iii) iv) and v) are on the same lines as that given in examples 4) and 5).