BHUBANANDAODISHASCHOOLOFENGINEERING, CUTTACK

DEPARTMENT OF CIVIL ENGINEERING

LECTURENOTEON: STRUCTURAL DESIGN II

(TH-2) 5TH SEMESTER

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Structural Steel Fasteners and Connections

Different elements/members of steel structures are required to be joined to one another either at their ends or at some intermediate length in order to facilitate the transmission/distribution of member forces.

Connections are also required for extending the lengths of members or for joining two parts of a structure during errection.

There are mainly four types of fasteners commonly used in practicle.

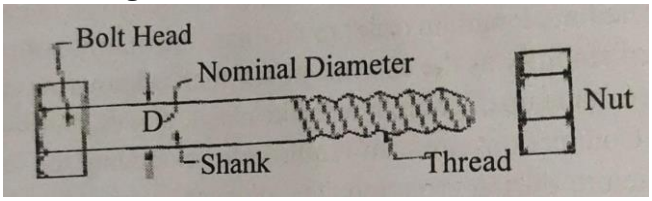
(a) Bolts
(b) Welds
(c) Rivets
(d) Pins

2.1 Bolted Connections

Bolted connections are a type of structural joint used to join two or more structural components in a steel structure using bolts.

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

A typical bolt and nut are shown in the figure.



2.1.1 Classification of bolts, advantages and disadvantages of bolted connections

Classification of bolts

Bolts are classified as

a. Unfinished bolts or black bolts
b. Finished bolts or turned bolts
c. High strength friction grip (HSFG) bolts.

Unfinished bolts or black bolts

These are also known as ordinary or common bolts. These bolts are made from low carbon mild steel round rods with square or hexagonal head and the shank is left unfinished or rough.

Finished bolts or turned bolts

These are close tolerance bolts which are formed from mild steel hexagonal rods and are made by turning to circular shape. Turned bolts may be either precision bolts or semi-precision bolts.
Tolerance allowed are about 0.15 mm to 0.5 mm.

High strength friction grip (HSFG) bolts

These bolts are made from high strength steel rods like black bolts, but the surface of the shank of these bolts is kept unfurnished and these bolts are tightened until very high tensile stresses are developed (called proof load) using calibrated wrenches so that the connected parts are clampled tightly together between the bolts and nut heads.
HSFG bolts are generally available in diameters of 16,20,24,30 and 36 mm being designated as M16, M20,. M30 etc.
These are now being used in high rise buildings, bridges etc.

Advantages of bolted connections

The following are the advantages of bolted connection over other type of connections.

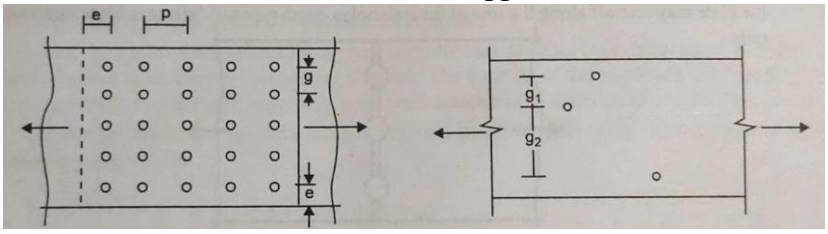
i. Use of simple tools and less skilled labour and working area.
ii. Speedy & noiseless errection.
iii. Economical due to reduced labour and equipment costs.
iv. Minimum strength reduction at joint due to less number of holes or bolts.
v. Easy alteration or dismantling of conncetions.

Disadvantages of bolted connection

i. High cost of material.
ii. Reduced tensile strength due to area reduction at the root of threads.
iii. Normally loose fit reduces joint rigidity leading to excessive deflection.
iv. Susceptibility to loosening of bolts under vibration and dynamic loads.
v. Large joint space, when heavy loads are required.

2.1.2 Different terminology, spacing and edge distance of bolt holes.

1. Pitch of bolts (p) - It is the distance between the centres of two consecutive bolts in a row measured along the direction of load.
Gauge distance (g) - It is the distance between two consecutive bolts of adjacent rows and is measured at right angles to the direction of load.
Edge distance / end distance (e) - It is the distance of centre of bolt hole form the adjacent edge or end of the plate.
Staggered pitch (p) - It is the centre to centre distance of staggered bolts measured along the direction of lood.
Staggered distance (s)- It is the centre to centre distance of staggered bolts measured obliquely on the member.



Specification on spacing and edge distance of bolt holes [clause 10.2 of IS 800 page 73 and 74]

1. Minimum pitch - Pitch shall not be less than 2.5d, where 'd' is the nominal diameter of bolt.
2. Maximum pitch - Pitch shall not be more than
   a. 16t or 200 mm, whichever is less, in case of tensile members.
   b. 12t or 200 mm, whichever is less, in case of compression members where 't' is the thickness of thinnest member.
   c. In case of staggered pitch, pitch may be increased by 50 percent of values specified above provided gauge distance is less than 75 mm.

3. In the case of compression members wherein forces are transferred through butting faces, this distance shall not exceed 4.5 times the diameter of the fasteners for a distance equal to 1.5 times the width of the member from the butting faces.
4. The gauge length 'g' should not be more than (100 + 4t) or 200 mm whichever is less.
5. Minimum edge distance shall be
   a. Not less than 1.7 times hole diameter in case of sheared or hand flame cut edges.
   b. Not less then 1.5 times hole diameter in case of rolled, machine flame cut, sawn and planed edges.
6. Maximum edge distance (e) should not exceed,
   a. 12tε, where $\varepsilon = \sqrt{\frac{250}{fy}}$ and t is the thickness of thinner outer plate.
   b. 40+ 4t, where t is the thickness of thinner connected plate.

7. Tacking bolts
   a. Apart from the bolts required to withstand design forces, additional bolts called tacking bolts are to be provided in a joint. When the value of gauge length is exceeded after making provision of design farteners (bolts) at maximum edge distances, tacking bolts should be provided.
      i. At 32 or 300 mm, whichever is less, if the plates are not exposed to weather.
      ii. At 16t or 200 mm, which ever is less, if the plates are exposed to weather.
   b. Where the members are made up of two flats, angles, channels or tees, tacking bolts are to be provided along the length of the member to connect its comprent parts at a spacing not exceeding
      i. 1000 mm in case of a tension member.
      ii. 600 mm in case of a compression member.

2.1.3 Types of bolted connections.

Broadly there are two types of bolted connections/joints.

1. Lap Joint
2. Butt Joint

Lap joint

In this type of joint, the two members to be connected overlap one another [Fig. 3.2 (a)].

This constitutes the simplest type of joint requiring no extra accessories like cover plates.

If there is one line of bolts, it is called single bolted lap joint [Fig. 3.2(b)] and if there are two lines of bolts, it is called a double bolted lap joint [Fig.3.2(c)].

Also chain bolted and zig-zag bolted lap joints are in use under different circumstances. [Fig. 3.2. (e)] & [Fig. 3.2.(f)]

In this case, the bolts are subjected to shear in one plane and hence known as bolts in single shear.

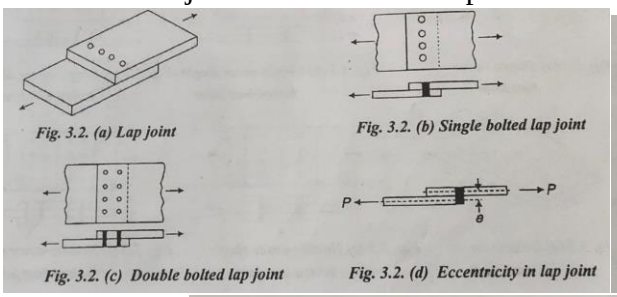


Fig. 3.2. (a) Lap joint

Fig. 3.2. (b) Single bolted lap joint

Fig. 3.2. (c) Double bolted lap joint

Fig. 3.2. (d) Eccentricity in lap joint

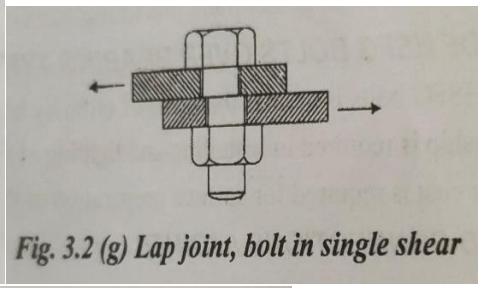


Fig. 3.2 (g) Lap joint, bolt in single shear

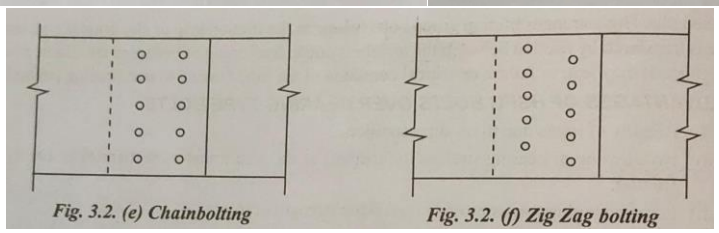


Fig. 3.2. (e) Chainbolting

Fig. 3.2. (f) Zig Zag bolting

Butt joint

In this type of joint, the two members to be connected are placed end to end i.e. butt against each other and the connection is made by providing additional plate/plates either on one side (single cover butt joint) or on both the sides (double cover butt joint). [Fig. 3.3.].

These additional plates are called cover plates whereas the members to be joined are called main plates.

Depending upon the number of lines of bolts on either side of the butting plane, the butt joints are known as single bolted, double bolted or tripple bolted butt joint as the case may be.

In case of double cover butt joint, bending is eliminated as there is no eccentricity of forces and the bolts are subjected to shear in two planes, known as bolts in double shear. [Fig. 3.3. (g)].

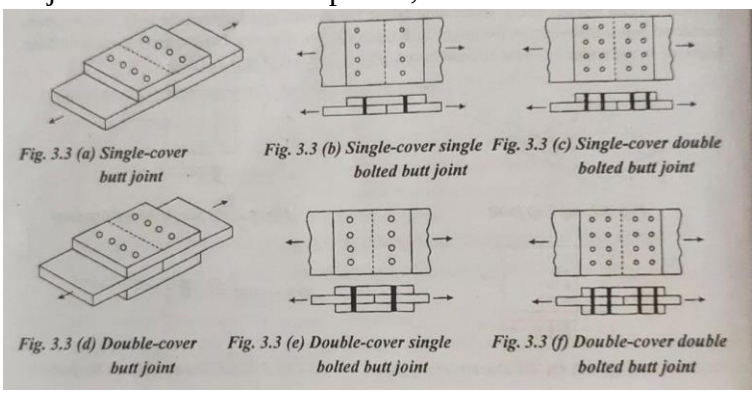


Fig. 3.3 (a) Single-cover butt joint

Fig. 3.3 (b) Single-cover single bolted butt joint

Fig. 3.3 (c) Single-cover double bolted butt joint

Fig. 3.3 (d) Double-cover butt joint

Fig. 3.3 (e) Double-cover single bolted butt joint

Fig. 3.3 (f) Double-cover double bolted butt joint

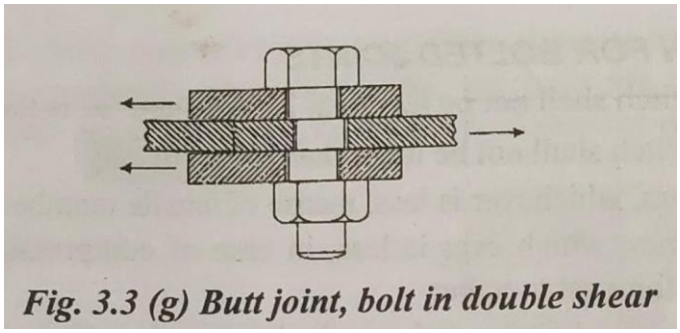


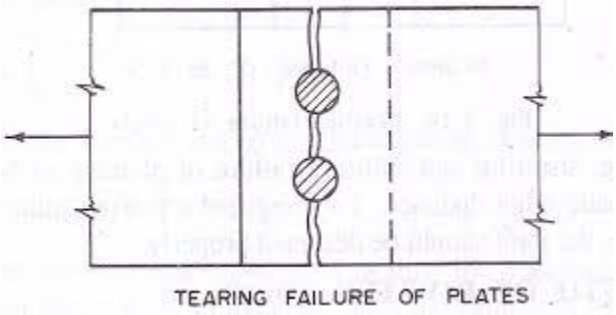
Fig. 3.3 (g) Butt joint, bolt in double shear

2.1.4 Types of action of fasteners, assumptions and principles of design

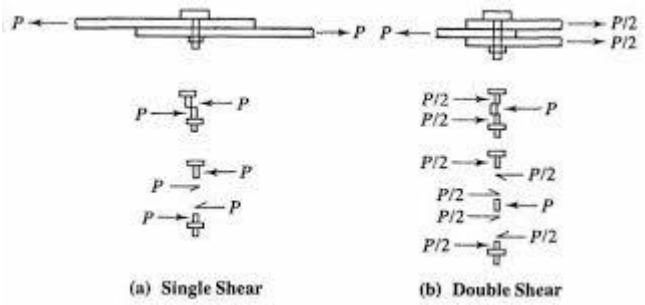
Types of action of fasteners

A bolted joint may fail in any of the following manners.

1. **Rupture of the plate between bolt holes** - The strength of the plate is reduced by bolt holes and the plate may tear off along the line of the bolt holes. Such types of failure is for tension members only.



TEARING FAILURE OF PLATES



2. **Shearing of bolt** - The bolts may fail by shearing if the shearing stress exceeds their shearing strength. In lap joints and single cover butt joints, the bolts are sheared at one plane only. In a double cover butt joint, the bolts are sheared at two planes.
3. **Bearing of bolt or plate** - The plate or bolt is crushed if the compressive stress exceeds the bearing strength of the plate or bolt.
4. **Bursting or cracking of the edge** - The plate will crack at the back of a bolt, if it is placed very near to the edge of the plate as shown in the fig. 3.5 (f). Such type of failure can be prevented if the provision of the minimum edge distance are satisfied.

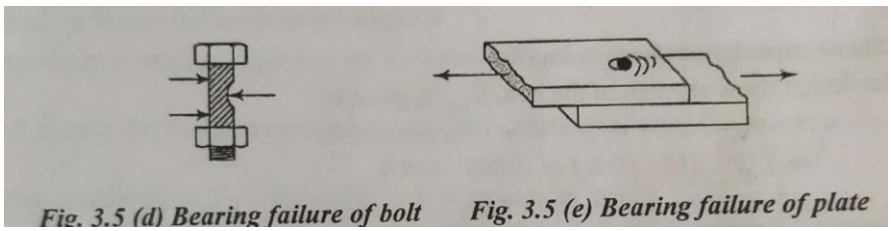


Fig. 3.5 (d) Bearing failure of bolt

Fig. 3.5 (e) Bearing failure of plate

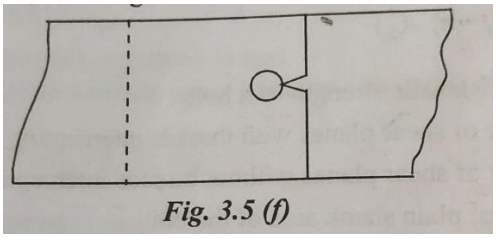


Fig. 3.5 (f)

The first three types of failures determine the strength of a joint. The bolt value or strength of bolt is determined by the types of failures described in 2 and 3 i.e. shearing and bearing of bolts.

Assumptions in the analysis of bearing bolts

The analysis of bolted joints is very complex and to simplify it, the following assumptions are made in the design of bearing type of (finished or unfinished) bolted connections.

i. The stress distribution on the plates between the bolt holes is uniform.
ii. The friction between the plates is negligible.
iii. The shearing stress is uniformly distributed over the cross-section of the bolts.
iv. The bolts in a group share the direct load equally.
v. Bending stresses developed in bolts is neglected.

Principles of bolted joint connections

The following guiding principles are to be observed in the design of bolted connections.

i. The arrangement of bolts should satisfy the gauge, pitch and the edge distance requirements.
ii. To effect economy of material cost in respect of cover plates, gusset plates etc. the length of the connection is kept as small as possible.
iii. The C.G of the bolt group should coincide with the centre line of connected members.
iv. The centre line of all members meeting at a joint should coincide at one point only to avoid twisting the joint out of position.
v. The number of bolts should be gradually increased towards the joint for uniform stress distribution in the bolts.
vi. Where possible, zig zag or diamond form of bolting may be adopted so as to effect minimum strength reduction due to holes.

2.1.5 Strength of plates in a joint, strength of bearing type bolts (shear capacity& bearing capacity), reduction factors, and shear capacity of HSFG bolts.

Strength of plates in a joint [clause 6.3.1 of IS 800 page 32]

The design tensile strength of a plate in the joint is the strength of the thinner member against rupture which is given by

$$T_{dn} = \frac{0.9Anfu}{\gamma ml}$$

Where γml = partial safety factor for failure at ultimate stress (see Table 5 page 30 IS 800),

f_u = ultimate stress of the material, and

A_n = net effective area of tbe member given by,

$$A_n = \left[b - nd_h + \sum_i \frac{p_{si}^2}{4g_i} \right] t$$

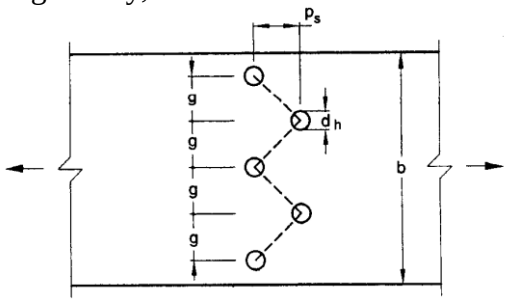


FIG. 5 PLATES WITH BOLTS HOLES IN TENSION

Where,

b, t = width and thickness of the plate, respectively

d_h = diameter of the bolt hole (table 19 page 73 IS 800)

g = gauge length between the bolt holes, as shown in Fig. 5,

P_s = staggered-pitch length between line of bolt holes, as shown in Fig. 5,

n = number of bolt holes in the critical section, and

i = subscript for summation of all the inclined legs