

**GANTRY GIRDER: Characteristics, Codal Provisions and Other Considerations**

# GANTRY GIRDER

## Introduction

In manufacturing plant it is essential to provide overhead travelling crane to transport heavy components of machines from one place to another. The movement of the load is of three dimensional nature. The crane is required to lift heavy mass vertically and horizontally, also the crane with load is required to move along the length of the shed. The cranes are either hand-or-electrically operated. The crane moves on rails which are at its ends. The rails are provided on a girder known as a gantry girder. The gantry girder spans over gantry columns. If capacity of crane is moderate, the gantry girders rest on brackets connected to roof column of industrial shed.

### Characteristics

- Design of gantry girder is a classic example of laterally unsupported beam
- It is subjected to in addition to vertical loads and horizontal loads along and perpendicular to its axis
- Loads are of dynamic nature and produce vibration
- Compression flange requires critical attention

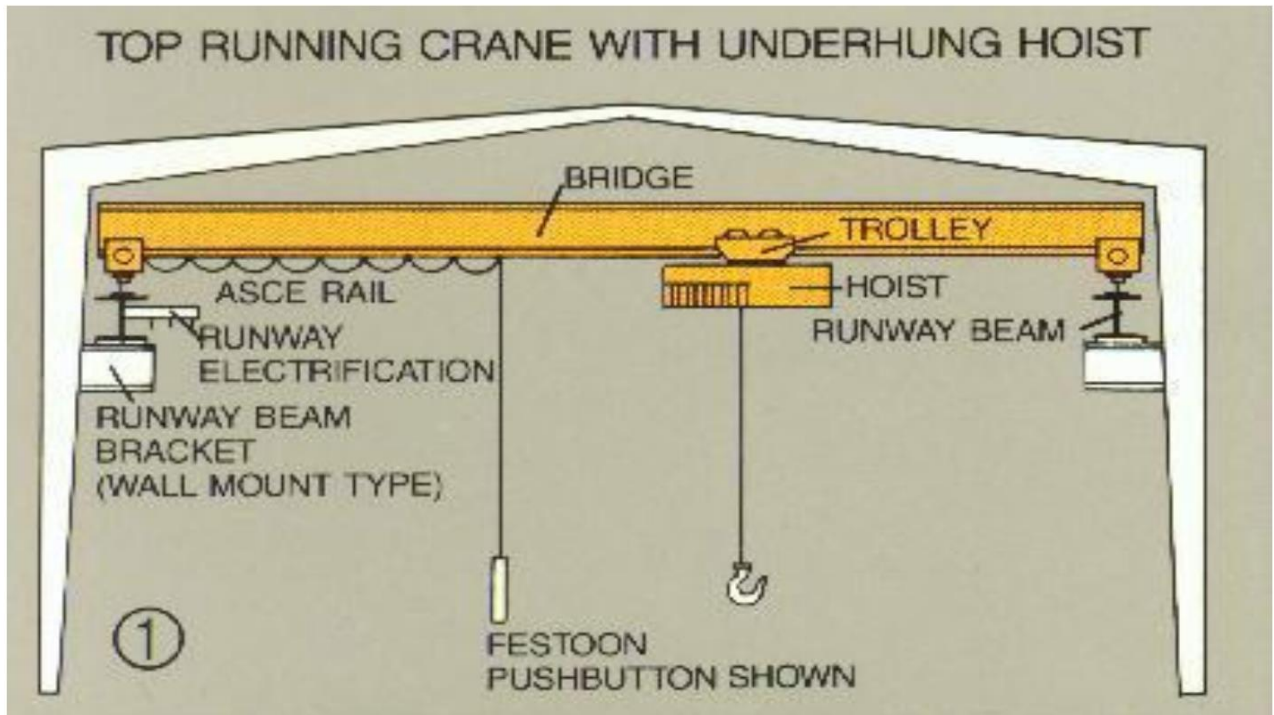
### Codal Provisions

- Partial safety factor for both dead load and crane load is 1.5
- Partial safety factor for serviceability for both dead load and crane load is 1

Category	Maximum Deflection
Vertical deflection	<ul style="list-style-type: none"><li>• Manually Operated – Span/500</li><li>• <input type="checkbox"/> Electric operated Span/750 upto 50t capacity</li><li>• Electric operated- Span/1000 over 50t capacity</li></ul>
Lateral deflection	<ul style="list-style-type: none"><li>• Relative displacement between rails supporting 10 mm or crane- span/400</li></ul>

### Other Considerations

- Diaphragm must be provided to connect compression flange to roof column of industrial building to ensure restraint against lateral torsional buckling at ends.
- Span is considered to be simply supported to avoid bumping effect.



### DESIGN PROCEDURE

In the design of gantry girders it is assumed that the lateral load is resisted entirely by the compression flange. The assumption is fairly justified because if the tension flange is to assist in resisting lateral load applied to the compression flange it must be pushed sideways by the web. But the lateral stiffness of the web is quite small as compared to that of the compression flange.

Step by step procedure is

1. **The maximum wheel load is determined.** The worst case of loading occurs when the crane and its load are drawn to the column. Therefore, the maximum vertical load is obtained when the crab is closest to the gantry girder. This distance is the minimum approach of the crane hook to the gantry girder. The crab in such a position on the crane girder gives the maximum reaction on the gantry girder. The vertical reaction of the crane girder is transferred through its two wheels on to the gantry girder. Therefore, the maximum wheel load is half of this reaction.
2. **The maximum bending moment in the gantry girder due to vertical loads is computed.** This consists of the bending moment due to the above found maximum wheel loads and the bending moment due to the dead load of the girder and rails. The bending moment due to dead loads is maximum at the centre of the span. At the point where the bending moment due to the wheel load is maximum (below one of the wheels of the crane girder) the dead load bending moment is slightly less than the

maximum dead load bending moment, but for simplifying the calculations the maximum bending moment due to the dead loads may directly be added to the maximum wheel load moment.

3. **The maximum shear force is computed.** This consists of shear force due to wheel loads and dead loads from the gantry girder and rails. The shear due to the wheel load is maximum when one of the wheels is at the support (if only one crane is running over the girder).
4. The lateral forces on the girder and the maximum bending moments and shear due these are calculated. The position of the wheels should be same as that in steps 2 and 3.
5. The plastic section modulus of the trial section is determined by

$$Z_p = Mu/f_y$$

$$Z_p (\text{trial}) = kZ_p, (k = 1.4-1.5)$$

Generally an I-section with a channel section on its top flange is provided. As the gantry girders are laterally unsupported the trial section modulus is usually 40 to 50 percent more than the calculated section modulus. Generally, the economical depth of a gantry girder is not less than 1/12 of the span except when the loads are small in relation to the span. The width of the flange should be between 1/40 to 1/30 of the span to prevent excessive lateral deflection.

6. **Section is classified.** Preference should be given to the flanges and web which can be classifiable as plastic.

$$b/t_f < 8.4 \quad (\text{for both I and channel sections separately})$$

$$d/t_w < 84$$

7. **The girder is checked for moment capacity.** The girder may be laterally supported or unsupported: the latter case being the most common.

$$M_d z = B_b Z_p f_y / \gamma_{mo} \leq 1.2 Z_e f_y / \gamma_{mo}$$

When lateral support is provided through out the compression (top) flange level of gantry girder by a catwalk or so, the trial section should be checked for the moment capacity of the whole section by the following equation

$$(M_y/M_{dy}) + (M_z/M_{dz}) \leq 1$$

The design bending strength so determined should be greater than the applied bending moment. When the compression flange is laterally unsupported, the girder is checked the same way but by replacing  $f_y$  with  $f_{bd}$ , the bending compressive stress.

8. **Local moment capacity of the girder is checked.** Combined local capacity of the flange is checked. The top flange should also be checked for bending about both the axes by the interaction equation
9. **The girder is checked for buckling resistance.** The elastic critical moment is calculated. This is valid for only I-section beams.
10. The section is checked for shear capacity

11. Buckling of the web under wheel load is checked. Buckling resistance =  $(b_1+n_1)t_{wc} >$  maximum wheel load where  $b_1$  = diameter of the wheel and  $n_1$  = dispersion length under wheel (assuming dispersion angle of 45°)
12. The girder is checked for bearing. If required bearing stiffeners are provided.
13. Rivets/bolts or welds connecting the channel to the I-section are designed.
14. Deflection of the gantry girder under service loads may be computed assuming, the wheel loads placed with their c.g. coinciding with the mid-span. The deflection so determined must be less than the permitted.
15. The girder is checked for fatigue strength
16. The bracket and its connection with column are designed. In case bolted connections are used, non-slip bolts should be preferred. A pair of bracket plates, one on each flange of I-section column, connected with a diaphragm is provided to make a seat for gantry girder.

### Impact factors

Type of load	Additional load
• <i>Vertical loads</i>	
a) EOT crane...	25% of static wheel load
b) HOT crane...	10% of static wheel load
• <i>Horizontal forces transverse to rails</i>	
a) EOT crane...	10% of wt. of crab & wt. lifted
b) HOT crane...	05% of wt of crab & wt. lifted
• <i>Horizontal forces along the rails</i>	
For both EOT & HOT cranes 05% of static wheel load	

### The basics

What is gantry girder and what are the forces that are acting on it?

A gantry girder, having no lateral support in its length, has to withstand vertical loads from the weight of the crane, hook load and impact and horizontal loads from crane surge.

### DESIGN OF CONNECTIONS

Connections shall be capable of transmitting the calculated design actions. In most structures connections are the weakest link. This leads often to failure in spite of the strong members used. This draws our attention to the design of connections with utmost care. The behaviour of connections is quite complex due to geometric imperfections and complexities, lack of fit, residual stresses etc; making it complex to analyse. This can be simplified by a number of assumptions and approximations based on past experience, experimental results and ductility of steel. It is the ductility of steel assists the distribution of forces generated within a joint.

The ultimate aim of connection design is to have a simple, compatible, feasible, easy to fabricate, safe and economical joint.

## TYPES OF CONNECTIONS.

Connection elements consist of components such as cleats, gusset plates, brackets, connecting plates and connectors such as rivets, bolts, pins, and welds. Connections are classified based on the connecting element and the fixity of the joint

### Classification based on the connector

Connections are classified based on the connecting element in to (a) Riveted, (b) Bolted, (c) Pinned and (d) Welded connection. Of these riveted, bolted and pinned connections behave in a similar manner.

### Classification based on the fixity of the joint

Based on the fixity of the joint, connections are classified in to (a) Rigid joint, (b) Semi rigid joint and (c) Flexible joints.

## SELECTIONS OF TYPE OF CONNECTION

Riveted connections were once very popular and are still used in some cases but will gradually be replaced by bolted connections. This is due to the low strength of rivets, higher installation costs and the inherent inefficiency of the connection. Welded connections have the advantage that no holes need to be drilled in the member and consequently have higher efficiencies. However, welding in the field may be difficult, costly, and time consuming. Welded connections are also susceptible to failure by cracking under repeated cyclic loads due to fatigue which may be due to working loads such as trains passing over a bridge (high-cycle fatigue) or earthquakes (low-cycle fatigue). A special type of bolted connection using High Strength Friction Grip (HSFG) bolts has been found to perform better under such conditions than the conventional black bolts used to resist predominantly static loading. Bolted connections are also easy to inspect and replace. The choice of using a particular type of connection is entirely that of the designer and he should take his decision based on a good understanding of the connection behaviour, economy and speed of construction. Ease of fabrication and erection

should be considered in the design of connections. Attention should be paid to clearances necessary for field erection, tolerances, tightening of fasteners, welding procedures, subsequent inspection, surface treatment and maintenance.

## BOLTED CONNECTIONS

Bolt is a metal pin with a head at one end and a shank threaded at other end to receive a nut, as shown in Figure 6. Steel washers are usually provided under the bolt head and nuts to prevent the treaded portion of the bolt from bearing on the connecting pieces and to distribute the clamping pressure on the bolted member.

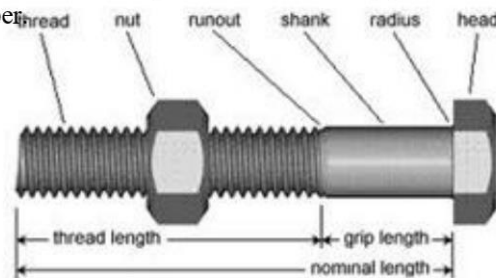


Figure A Bolt

A bolt connection can be used for end connections in tension and compression members. They can also hold down column bases in position and as separator for purlins and beams in foundations.

## Lecture 01

Bolts are having the following advantages over rivets and pins: (a) the erection of the structures can be speeded up. (b) Less skilled labour can be employed. (c) Overall cost of bolted connection is lesser than the other alternatives. However the following shortcomings are also associated with the bolted connections: (a) Cost of material is high, about double than that of rivets. (b) The tensile strength of bolt is reduced due to the reduced area at the root of the thread and stress concentration. (c) Normally strength reduction will be there for loose fit bolts. (d) Bolts may get loose when subjected to vibrations.

### CLASSIFICATION OF BOLTS

Bolts used in steel structures are of three types: 1) Black Bolts 2) Turned and Fitted Bolts and 3) High Strength Friction Grip (HSFG) Bolts.

The International Standards Organisation designation for bolts, also followed in India, is given by Grade x.y. In this nomenclature, x indicates one-tenth of the minimum ultimate tensile strength of the bolt in  $\text{kgf/mm}^2$  and the second number, y, indicates one-tenth of the ratio of the yield stress to ultimate stress, expressed as a percentage. Thus, for example, grade 4.6 bolt will have a minimum ultimate strength  $40 \text{ kgf/mm}^2$  (392 MPa) and minimum yield strength of 0.6 times 40, which is  $24 \text{ kgf/mm}^2$  (235 MPa).

#### Black bolts

Black bolts are unfinished and are made of mild steel and are usually of Grade 4.6. Black bolts have adequate strength and ductility when used properly; but while tightening the nut snug tight (“Snug tight” is defined as the tightness that exists when all plies in a joint are in firm contact) will twist off easily if tightened too much.

#### Turned and fitted bolts

Turned and fitted bolts have uniform shanks and are inserted in close tolerance drilled holes and made snug tight by box spanners. The diameter of the hole is about 1.5 to 2.0 mm larger than the bolt diameter for ease in fitting. High strength black bolts (grade 8.8) may also be used in connections in which the bolts are tightened snug fit. In these bearing type of connections, the plates are in firm contact but may slip under loading until the hole surface bears against the bolt. The load transmitted from plate to bolt is therefore by bearing and the bolt is in shear. Under dynamic loads, the nuts are liable to become loose and so these bolts are not allowed for use under such loading. In situations where small slips can cause significant effects as in beam splices, black bolts are not preferred. However, due to the lower cost of the bolt and its installation, black bolts are quite popular in simple structures subjected to static loading. Turned and fitted bolts are available from grade 4.6 to grade 8.8. For the higher grades there is no definite yield point and so 0.2% proof stress is used.

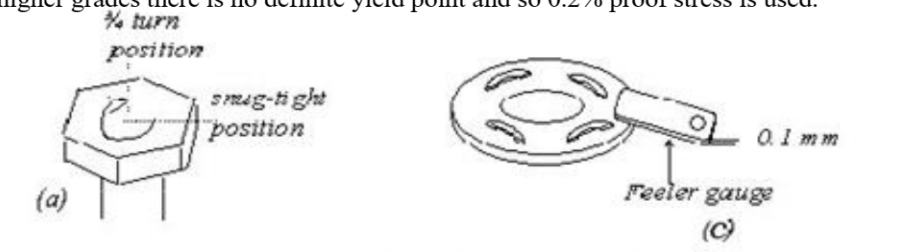


Figure Tightening of HSF bolts

#### High Strength Friction Grip bolts (HSFG)

High Strength Friction Grip bolts (HSFG) provide extremely efficient connections and perform

well under fluctuating/fatigue load conditions. These bolts should be tightened to their proof loads and require hardened washers to distribute the load under the bolt heads. The washers are usually tapered when used on rolled steel sections. The tension in the bolt ensures that no slip takes place under working conditions and so the load transmission from plate to the bolt is through friction and not by bearing. However, under ultimate load, the friction may be overcome leading to a slip and so bearing will govern the design. HSFG bolts are made from quenched and tempered alloy steels with grades

from 8.8 to 10.9. The most common are the so-called, general grade of 8.8 and have medium carbon content, which makes them less ductile. The 10.9 grade have a much higher tensile strength, but lower ductility and the margin between the 0.2% yield strength and the ultimate strength is also lower. The tightening of HSFG bolts can be done by either of the following methods (IS 4000):

- Turn-of-nut tightening method: In this method the bolts are first made snug tight and then turned by specific amounts (usually either half or three-fourth turns) to induce tension equal to the proof load (Figure 7(a)).
- Calibrated wrench tightening method: In this method the bolts are tightened by a wrench (Figure 7(b)) calibrated to produce the required tension.
- Alternate design bolt installation: In this method special bolts are used which indicate the bolt tension. Presently such bolts are not available in India.
- Direct tension indicator method: In this method special washers with protrusions are used (Figure 7(c)). As the bolt is tightened, these protrusions are compressed and the gap produced by them gets reduced in proportion to the load. This gap is measured by means of a feeler gauge, consisting of small bits of steel plates of varying thickness, which can be inserted into the gap.

Since HSFG bolts under working loads, do not rely on resistance from bearing, holes larger than usual can be provided to ease erection and take care of lack-of-fit. Typical hole types that can be used are standard, extra large and short or long slotted. These are shown in Figure 8. However the type of hole will govern the strength of the connection. Holes must also satisfy pitch and edge/end distance criteria (Cl.10.2 of IS 800:2007). A minimum pitch is usually specified for accommodating the spanner and to limit adverse interaction between the bearing stresses on neighbouring bolts. A maximum pitch criterion takes care of buckling of the plies under compressive loads

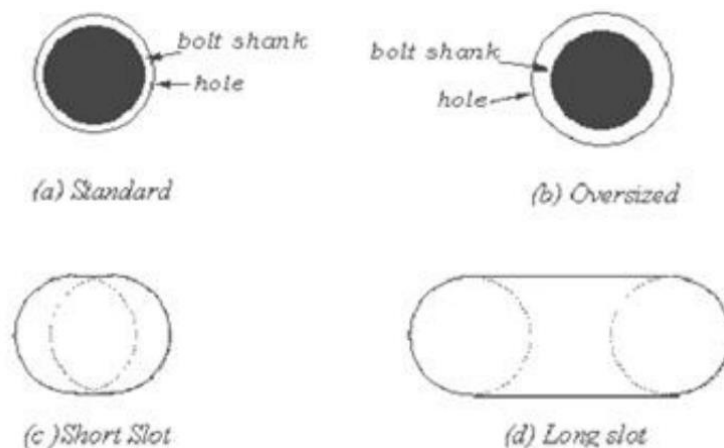


Figure Hole types for HSFG bolts

## CLASSIFICATIONS OF BOLT CONNECTIONS

Bolt connections are generally classified in the following ways

**Based on the resultant force transferred.**

Bolt connections can be classified into the following heads based on how the resultant force transferred at the joint. (a) Concentric connection - if the force transferred passes through the CG of the connection. Eg. Axially loaded compression and tension members. (b) Eccentric connection - if

the load is not passing through the CG of the connection. Eg. Bracket connection and seat connection.

(c) Moment resisting connection - when the joints are subjected to moments. Eg. Beam to column connection in framed construction.

Ideal concentric connections should have only one bolt passing through all the members meeting at a joint as shown in Figure 9(a). However, in practice, this is not usually possible and so it is only ensured that the centroidal axes of the members meet at one point as shown in Figure 9(b).

The Moment connections are more complex to analyse compared to the above two types and are shown in Figure 10(a) and Figure 10(b). The connection in Figure 10(a) is also known as bracket connection and the resistance is only through shear in the bolts. The connection shown in Figure 10(b) is often found in moment resisting frames where the beam moment is transferred to the column. The connection is also used at the base of the column where a base plate is connected to the foundation by means of anchor bolts. In this connection, the bolts are subjected to a combination of shear and axial

tension

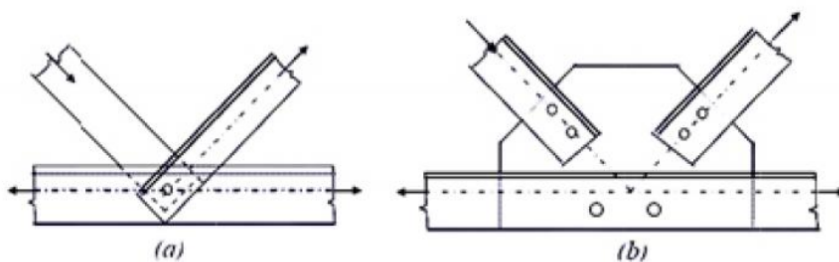


Figure 9 Concentric Connection

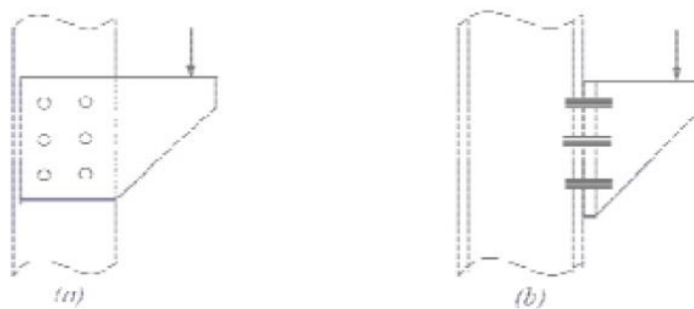
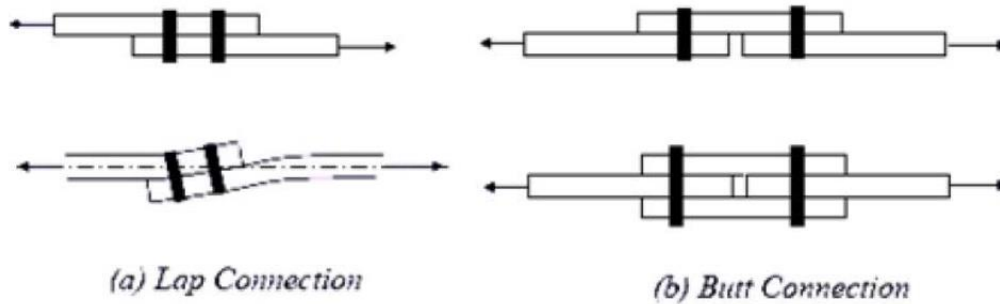


Figure 10 Moment Connection

**Based on the type of force**

Bolt connections can be classified into the following based on the type of force transferred: (a) Shear connection - when the load transfer is through shear. Eg. Lap joint and tension joint; (b) Tension joints - when load is transferred by tension in the bolts. Eg. Hanger connection; (c) Combined shears and tension connections - when load is transferred through the combinations of



shear and tension. Eg. Inclined members connected to columns or beams.

Typical shear connections occur as a lap or a butt joint used in the tension members as shown in Figure . While the lap joint has a tendency to bend so that the forces tend to become collinear, the butt joint requires cover plates. Since the load acts in the plane of the plates, the load transmission at the joint will ultimately be through shearing forces in the bolts.

In the case of lap joint or a single cover plate butt joint, there is only one shearing plane, and so the bolts are said to be in single shear. In the case of double cover butt joint, there are two shearing planes and so the bolts will be in double shear. It should be noted that the single cover type butt joint is nothing but lap joints in series and also bends so that the centre of the cover plate becomes collinear with the forces. In the case of single cover plate (lap) joint, the thickness of the cover plate is chosen to be equal to or greater than the connected plates. While in double cover plate (butt) joint, the combined thickness of the cover plates should be equal to or greater than the connected plates.

A hanger connection is shown in Figure 12(a). In this connection, load transmission is by pure tension in the bolts. In the connection shown in Figure 12(b), the bolts are subjected to both tension and shear.

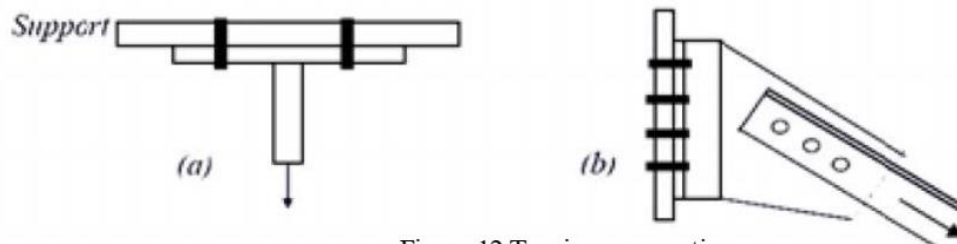


Figure 12 Tension connection

**. On the basis of force transfer mechanism**

Bolt connections are classified into the following based on the way in which load is transferred from one member to another connected in the joint. (a) Bearing type - bolts bear against the holes to transfer the load from one member to another. Eg. Slip type connection. (b) Friction type - when the force is transferred by friction between the plates due to tensioning of bolts. Eg. Slip-critical connects.

**FAILURE OF BOLTED CONNECTIONS**

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Failure of bolted connection can be classified broadly in to two: (1) failure of the bolt and (2) failure of connecting parts. Bolted joints may fail in any of the following six ways

- Shear failure of bolts.
- Bearing failure of bolts.
- Bearing failure of plates
- Tension failure of bolts.
- Tension or tearing failure of plates.
- Block shear failure.

The specification of Bolted joints will be discussed on lecture two

## Lecture 01

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