Fasteners used in Various Place on Steel Structure Elements

Dr. Sanjeev Gill[1] Dr. Rajiv Kumar[2]
[1]Head of Department [2]Associate Professor & Dean
[1]Department of Civil Engineering [2]Department of Computer Science & Engineering
[1]JBIT, Dehradun (U.K), India [2]N. C. College of Engineering Israna, Haryana, India

Abstract— In this various elements of steel structure like tension member, compression member and flexural member are connecting by fasteners or connectors. Many a times, built-up sections are provided to meet the requirements of heavy loads and long spans. Such sections also need to be connected together to act in unison as one unit. The forces exerted by one element on another are transferred through these fasteners, which should therefore be adequate to transmit the forces safely. Only properly connected and detailed members and connections can transfer the forces safely from top to the foundation. Different types of fasteners available for making connections are rivets, bolts, pins and welds. Today, steel structures are constructed with bolting or welding or by combination of both. To simplify the analysis and design, a number of assumptions and approximations are made based on experimental results, past performance and ductility of steel. The ultimate aim of connection design is to produce a joint that is simple, compatible, feasible, easy to fabricate and is safe and economical.

Key words: Tension Members, Compression Members, Steel Structure, Fasteners, Joints

I. Introduction

In general, fasteners are used to create non-permanent joints; that is, joints that can be removed or dismantled without damaging the joining components. Welding is an example of creating permanent joints. There are three major steel fasteners used in industries, stainless steel, carbon steel and alloy steel. The major grade used in stainless steel fasteners 200 series, 300 series and 400 series. Other alternative methods of joining materials include crimping, welding, soldering, brazing, taping, gluing, cementing or the use of other adhesives. The use of force may also be used, such as with magnets, vacuum or even friction. Some types of woodworking joints make use of separate internal reinforcements, such as dowels or biscuits which in a sense can be considered fasteners within the scope of the joint system, although on their own they are not general purpose fasteners. Fasteners can also be used to close a container such as a bag, a box, or an envelope or they may involve keeping together the sides of an opening of flexible material, attaching a lid to a container, etc. There are also special-purpose closing devices. Cable, chain or plastic wrap may be used to mechanically join objects but are not generally categorized as fasteners because they have additional common uses.

II. Types of Fasteners

A. Riveted Connection

The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail. The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals. Because there is effectively a head on each end of an installed rivet, it can support tension loads parallel to the axis of the shaft. However, it is much more capable of supporting shear loads perpendicular to the axis of the shaft. Bolts and screws are better suited for tension applications.

B. Bolted Connection

Bolted joints are one of the most common elements in construction and machine design. They consist of fasteners that capture and join other parts, and are secured with the mating of screw threads. There are two main types of bolted joint designs: tension joints and shear joints.

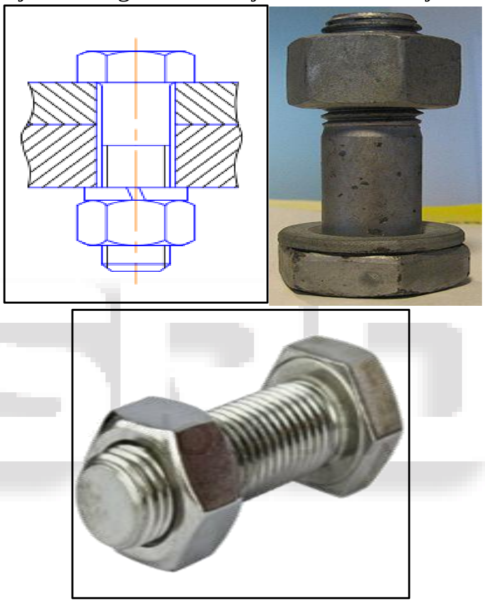

Fig. 1:

There are two main types of bolted joint designs: tension joints and shear joints.

In the tension joint, the bolt and clamped components of the joint are designed to transfer an applied tension load through the joint by way of the clamped components by the design of a proper balance of joint and bolt stiffness.

The second type of bolted joint transfers the applied load in shear of the bolt shank and relies on the shear strength of the bolt. Tension loads on such a joint are only incidental. A preload is still applied but consideration of joint flexibility is not as critical as in the case where loads are transmitted through the joint in tension.

C. Welded Connection

A welding joint is a point or edge where two or more pieces of metal or plastic are joined together. They are formed by welding two or more work pieces (metal or plastic) according to a particular geometry. Five types of joints referred to by the American Welding Society: butt, corner, edge, lap, and tee. These configurations may have various configurations at the joint where actual welding can occur.

III. Methods

Design of steel structures consists of design of steel members and their connections so that they will safely and economically resist and transfer the applied loads. This involves the knowledge of material properties, load and factor of safety.

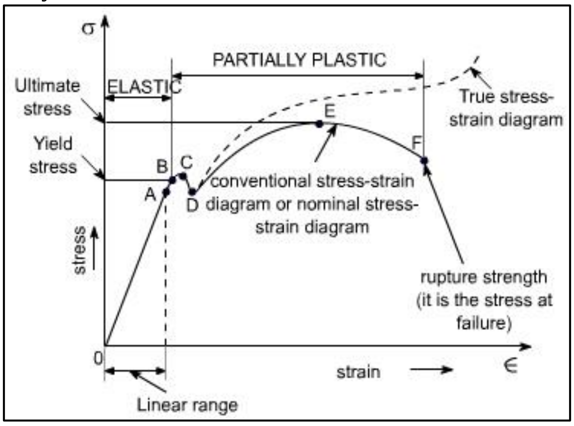

Fig. 2:

Although the ease of fabrication and feasibility of connections of various members may ultimately dictate the choice, the process beings with the sections of a section with minimum weight per unit length. Once the trial section selected, the designer checks it's safely.

As of today there are three design philosophies for the design of steel structures:

1) Elastic or Working stress method
2) Plastic or Ultimate load method
3) Limit state method

A. *Elastic or Working Stress Method*

Working stress design, the traditional method of designing steel structures, is based on elastic theory. The working stress in the member should be less than the permissible stress. The permissible stress for fasteners are usually based on the ultimate strength of the connection using safety factor values of about 2 to 3 for fasteners. The code of practice IS: 800 - 1984 is based on the working stress method of design. It's a traditional method used for reinforced concrete design where concrete is assumed as elastic, steel and concrete act together elastically where the relationship between loads and stresses is linear. Assumption Bond between steel and concrete is perfect with in elastic limit of steel.

B. *Plastic or Ultimate Load Method*

The design criterion is the ultimate strength and hence the behavior of members beyond the yield stress in the inelastic or plastic range is considered. This method of design is based on failure conditions rather than working load conditions. This method of design is based on failure conditions rather than working load conditions. Failure implies collapse or extremely large deformation. The structure fails at a much higher load, called the collapse load, than the working load. The working loads are multiplied with specified factors, known as load factors. The terms plastic is used because at failure parts of the members will be subjected to very large strains. In the mechanism or kinematics method of plastic analysis, various plastic failure mechanisms are evaluated. The plastic collapse loads corresponding to various failure mechanisms are obtained by equating the internal work at the plastic hinges to the external work by loads during the virtual displacement.

C. *Limit State Method*

The limit state design method was developed to take account of all conditions that can make the structure unfit for use, considering actual behavior of materials and structures. The design method considers most critical limit states of strength and serviceability. In limit state design, basically statically methods have been used for determination of loads and material properties with a small probability of structure reaching the limit state of strengths and serviceability. The design strength always greater than the design action. The stresses are obtained from design loads and compared with design strength. In this method, it follows linear strain relationship but not linear stress relationship (one of the major difference between the two methods of design). The ultimate stresses of materials itself are used as allowable stresses

IV. Design procedure of fasteners

A. *Riveted Connection*

For the design of a lap joint or butt joint, the thickness of plates to be joined is known and the joints are designed for the full strength of the plate. For the design of a structural steel work, force (pull or push) to be transmitted by the joint is known and riveted joints can be designed. Following are the usual steps for the design of the riveted joint:

1) Step 1: Bearing strength of rivet

The bearing strength of rivets is the force that can be exerted on it by the section through which it passes. Bearing strength of rivet = Projected area * Permissible bearing strength

$P_b = n{*}dt * f_b$

P_b = Bearing strength of rivet

d = Gross diameter of rivet

t= thickness of Plates

n = number of rivet

$f_{b\,=}$ Permissible bearing strength

2) Step 2: Shearing strength of rivet

The rivet shank shears along the place of slips. The numbers of planes along which the rivet can be sheared indicates the number of shears; i.e. Single shear, Double shear

Shear strength of rivet = Cross-section area * Permissible Shearing strength

$P_s = n{*}0.785d^2 * f_s$

$P_{s\,=}$ Shear strength of rivet

$f_{s\,=}$ Permissible Shearing strength

3) Step 3: Tearing strength of plates

Tearing strength of plates depends upon the net section resisting the forces.

Tearing strength of plates = Net area along the section * Permissible tensile stress in the plate

$P_t = (B-nd){*}t{*}f_t$

P_t = Tearing strength of plates

f_t = Permissible tensile stress in the plate

B = Width of the plate

4) Step 4: Efficiency of riveted joints

This is also called as the percentage strength of riveted joints. It is the ratio of strength of rivet joint and strength of solid plates.

Efficiency of riveted joints = (strength of rivet joint)*100/(strength of solid plates)

5) Step 5: Rivet Value

The minimum strength of a rivet inn shear or bearing is called as the rivet value. It's represented by R_V.

B. Bolted Connection

1) Step 1: Shearing strength of bolts

The shearing of bolts can take place in the threaded portion of the bolt and so the area at the root of the threads, also called the tensile stress area A_t, is taken as the shear area A_S. Since threads can occur in the shear plane, the area A_e for resisting shear should normally be taken as the net tensile stress area, An Of the bolts. The shear area is specified in the code and is usually about 0.8 times the shank area. However, if it is ensured that the threads will not lie in the shear plane then the full area can be taken as the shear area.

$V_{nsb} = 0.577\,(n_n A_{nb}+n_S A_{sb})$

V_{nsb} = Nominal capacity of bolts

f_{ub} = ultimate tensile stress of the bolt

n_n = number of shear planes with threads interceptinng the shear plane

A_{nb} = Net tensile stress area

n_S = number of shear planes without threads interceptinng the shear plane

A_{sb} = Cross area of the shank

Shearing strength of bolts

$V_{dsb} = V_{nsb}/y_{mb}$

V_{dsb} = Shearing strength of bolts

y_{mb} = partial safety factor for the material of bolt(1.25)

2) Step 2: Bearing strength of bolts

The design for friction type bolting in which bearing stress in the ultimate limit state is required to be limited. Except the design bearing strength of a bolt on any plate, V_{dpb} as governed bearing strength is given by

$V_{dpb} = V_{npb}/y_{mb}$

V_{dpb} = bearing strength of a bolt

V_{npb} = Nominal bearing strength of a bolt

$V_{npb} = 2.5\, k_b*d*t(f_u/ y_{mb})$

3) Step 3: Tearing strength of bolt

The nominal tensile capacity of bolt subjected to factored tensile force is given by

$T_{nb} = 0.9f_{ub}\, A_{nb} < f_{yb}\, A_{sb}\, (y_{mb}/y_{mo})$

T_{nb} = Normal tensile capacity

y_{mo} = partial safety factor for the material resistance governed by yielding (1.10)

The bolt is safe in tension if the factored tension force is less than the design tensile strength of the bolt. The tensile strength of bolt in tension is given by

$T_{db} = (T_{nb}/y_{mb})$

T_{db} = the factored tension force

4) Step 4: Tensile strength of the plate

If the tensile load on the plate is more than the tensile strength of the plate. The plate fails in tension through rupture. The tensile strength of the plate is given by

$T_{nd} = 0.9\, A_n * (f_u/y_{m1})$

A_n = the effective net area of plate

y_{m1} = = partial safety factor

5) Step 5: Efficiency of bolted joints

This is also called as the percentage strength of bolted joints. It is the ratio of strength of bolt joint and strength of solid plates.

Efficiency of bolted joints = (strength of bolted joint)*100/ (strength of solid plates)

C. Welded Connection

1) Step 1: Size of fillet weld

The size of normal fillet weld is specified as minimum leg length of a convex or miller fillet weld or 1.414 times the effective throat thickness of a concave fillet weld. The size of deep penetration fillet weld is specified as minimum leg length plus 2.4 mm. the length of leg is the distance from the root to the toe of a fillet weld, measured along the fusion face.

2) Step 2: Effective throat thickness

The effective throat thickness of a fillet weld is the perpendicular distance from the root to the hypotenuse of the largest isosceles right angled triangle that can be inscribed within the weld cross section. The effective throat thickness of a fillet weld shall not be less than 3 mm and shall generally not exceed 0.7 times the thickness of thinner part and equal to the thickness of thinner part under special circumstances.

$$Effective\ throat\ thickness = \frac{1}{\sqrt{2}} \times Size\ of\ weld = 0.7 \times Size\ of\ weld$$

In general, for the purpose of stress calculation,

$$Effective\ throat\ thickness = K \times Size\ of\ weld$$

Where, K is a constant. The value of K for different angles between fusion faces is adopted as per Table 7.1 as recommended in IS: 816-1969

S.NO	Angle between fusion faces	Value of constant K
1	60˚ -90˚	0.70
2	91˚-100˚	0.65
3	101˚-106˚	0.60
4	107˚-113˚	0.55
5	114˚-120˚	0.50

Table 7.1 Value of K for Different Angles between Fusion Faces

3) Step 3: Effective length

The effective length of the weld is the length of the weld for which the specified size and throat thickness i.e., correctly proportioned cross section of the weld, exist. It is taken as the actual length minus twice the size of weld, since the specified size and throat thickness do not exist at the ends. The effective length of the weld is shown on the drawings. In practice the actual length of weld is made equal to the effective length shown on the drawing plus twice the weld size. The effective length of fillet weld should not be less than four times the size of the weld.

4) Step 4: Shearing strength of welds

The design shear strength of the weld

$V_{dw} = 0.577\, l_w\, t_e\, (f_{yw}/y_{mw})$

V_{dw} = design shear strength of the weld

l_w = effective length of the weld

f_{yw} = ultimate tensile stress of weld

y_{mw} = partial safety factor for the material

Step 5: Bearing strength of welds

The Bearing strength of weld is given by

$F_{dw} = 1.2\, Z_e\, (f_y/ y_{mo})$

F_{dw} = Bearing strength of weld

Z_e = The section of modulus

V. ADVANTAGES & DISADVANTAGES OF RIVETED JOINTS

A. *Advantages of Riveted Joints*

- A riveted joint is more reliable than welded joints in applications which are subjected to vibrations and impact forces.
- Riveted joints can be used for non-ferrous metals like aluminum alloy, copper, brass or even non-metal like plastic and asbestos.
- Riveted joints are free from thermal after-effect because no heat required in this joint.
- Quality inspection is easy in riveted joint.
- When the riveted joint is dismantled, the connected components are less damaged as compare to welded joint.

B. *Disadvantages of Riveted Joints*

Material cost of riveted joint is more.

- The labor cost of riveted joints is also more than that of the welded joint.
- Overall cost if riveted joint is also high.
- Riveting process creates more noise because of hammer blows.
- Holes required inserting rivets cause stress concentration.
- Production time is more for assembly.
- Riveted assemblies are not tight and leak proof.

VI. ADVANTAGES & DISADVANTAGES OF BOLTED JOINTS

A. *Advantages of Bolted Joints*

- They are easily disassembled, as opposed to something like riveting or welding, which requires cutting.
- Welds require heating a metal, which can change the properties in the heat-affected zone, and can also create thermal stresses. Bolts avoid this problem.
- Bolted joints aren't particularly sensitive to the condition of the parent material.
- You can put a bolt in a blind hole
- Bolts are easy. Welding takes a lot of skill and a lot of time
- Bolts offer much better joint quality than a screw, mostly because the threads are more tightly controlled.

B. *Disadvantages of Bolted Joints*

- They can become loose over time as the nut backs or as the material creeps. Welding and adhesive joints don't have this problem.
- They require holes, which introduce stress concentrations and more failure modes; drilling the holes may create cracks which will grow over time to cause failure.
- Preload can be tough to measure accurately - it depends on the method of tightening, the friction between the threads of the bolt and the nut, etc.
- Damage to a threaded hole is tough to replace - you can drill it out and rethread, but using a larger bolt might change your load distribution.
- Corrosion between a bolt and the parent material should be considered.
- Bolted joints require a gasket to seal a joint. A weld will be leak-proof.

VII. ADVANTAGES & DISADVANTAGES OF WELDED JOINTS

A. *Advantages of Welded Joints*

- No hole is required for welding
- Reduced overall weight of the structure.
- Less material is required.
- It is more than that of the riveted joint.
- The speed of fabrication is faster in comparison

B. *Disadvantages of Welded Joints*

- Welded joints are more brittle and therefore their fatigue strength is less than the members joined.
- Due to uneven heating & cooling of the members during the welding, the members may distort resulting in additional stresses.
- Skilled labor and electricity are required for welding.
- No provision for expansion and contraction is kept in welded connection & therefore, there is possibility of racks.
- The inspection of welding work is more difficult and costlier than the riveting work.

VIII. CONCLUSIONS

- It is important to control the weight, stiffness, strength and the ductility of the material of the elements.
- This is due the fact that their behavior depends on the mentioned parameters of the elements in the connections From the comparative experimental analysis of all of the researched models
- it can be concluded that the capacity of the carrying of the bending moment of the models with rigid connection is significantly bigger than the one with the semi rigid connections
- ; if the rigid connections are separately analyzed (the deformation (rotation) capability in the researched models is inversely proportional to the capacity of carrying of the beam i.e. the semi rigid connections have bigger plastic deformability and possibility for bigger rotation during the use of their total capacity
- To carry, but they have smaller capacity to carry comparing to the ones with rigid connection. The main idea and direction for further researches is obtaining one beam-column connection

REFERENCES

[1] S. K. Duggal Professor and Head, Motilal Nehru National Institute of Technology, Allahabad Uttar Pradesh,

[2] Indian Standard GENERAL CONSTRUCTION IN STEEL-CODE IS:800 2007 OF PRACTICE (Third Revision)

[3] R.Englekirk, “STEEL STRUCTRURES”, University of California at Los Angeles, (1994).

[4] Gupta B.L. Head of Civil Engineering Department, Standard Publication, Delhi5) Prashant Dixit Chief Executive Engineer, Arihant Publication, New Delhi
[5] B. Singh (Ex.IES) Founder & Director, MADE EASY Group