Steel Structure Design

Introduction

Structural steel is a category of steel used for making construction materials in a variety of shapes. Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section.

Properties of steel

1. $R= 7850kg/m^3$

2. $E=2\times105N/mm^2$

3. Poison ratio=0.3

Mechanical properties

Type-1	Designation	UTS(MPa)	Yield strength (MPa)		
			Thickness(mm)		
			≤ 20	20-40	≥ 40
Standard structural steel	Fe 410A	410	250	240	230
	Fe410B	410	250	240	230
	Fe410C	410	250	240	230
High tensile structural steel	St58HT	580	360	0.05	1.00
	ST55-HTW	550	360	0.05	1.00

Grade

FE 410AW weldable

Iron Ultimate tensile strength

Ductility

Ability of material to change its shape without fracture

Mild steel - high ductility

High carbon steel - low ductility

Toughness & brittle fracture

1. Ability of material to resist impact load like earthquake load, machine load etc.
2. At low temp. Steel fall on impact loading due to reduction in ductility and toughness called brittle fracture

Temperature -

At high temp strength reduce.

Hardness-

1. Resistance of the material to intension and scratching.
2. Brinell harness, rockwell hardness number are used to measure hardness.

sssss

Fatigue -

1. Damage of material to cyclic loading
2. Occur due to moving load , vibration in bridge

Riveted Connection

Rivets and Riveting: A Rivet is a short cylindrical rod having a head and a tapered tail. The main body of the rivet is called shank

Rivet heads used for boiler works

Depending upon whether the rivet is initially heated or not, the riveting operation can be of two types: (a) cold riveting riveting is done at ambient temperature and (b) hot riveting rivets are initially heated before applying force. After riveting is done, the joint is heat-treated by quenching and tempering. In order toensure leak-profaneness of the joints, when it is required, additional operation like caulking is done .

Types of riveted joints and joint efficiency: Riveted joints are mainly of two types

1. Lap joints
2. Butt joints

Lap Joints -The plates that are to be joined are brought face to face such that an overlap exists,Rivets are inserted on the overlapping portion. Single or multiple rows of rivets are used to give strength to the joint. Depending upon the number of rows the riveted joints may be classified as **single riveted lap joint, double or triple riveted lap joint** etc

Butt Joints- In this type of joint, the plates are brought to each other without forming any overlap. Riveted joints are formed between each of the plates and one or two cover plates. Depending upon the number of cover plates the butt joints may be **single strap or double strap butt joints**

Important terms:-

a) **Pitch:** This is the distance between two centers of the consecutive rivets in a single row. (usual symbol p)

b) **Back Pitch**: This is the shortest distance between two successive rows in a multiple riveted joint

c) **Diagonal pitch:** This is the distance between the centers of rivets in adjacent rows of zigzag riveted joint. (usual symbol pd)

d) **Margin or marginal pitch:** This is the distance between the centre of the rivet hole to the nearest edge of the plate. (usual symbol m)

FAILURES OF A RIVETED JOINT

Failures of a Riveted Joint:

A riveted joint may fail in the following ways :

1. Tearing of the plate at an edge. A joint may fail due to tearing of the plate at an edge as shown in Fig. This can be avoided by keeping the margin, m = 1.5d, where d is the diameter ofthe rivet hole.

2.Tearing of the plate across a row of rivets. Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets as shown in Fig. In such cases, we consider only one pitch length of the plate, since every rivet is responsible for that much length of the plate only.

3. Shearing of the rivets. The plates which are connected by the rivets exert tensile stress onthe rivets, and if the rivets are unable to resist the stress

4. Crushing of the plate or rivets. Sometimes, the rivets do not actually shear off under thetensile stress, but are crushed Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The failure of rivets in such a manner is also known asbearing failure.

Strength of riveted joint:

strength of joint is usually calculated considering one pitch length of the plate. There are four possible ways a single rivet joint may fail

. **a) Tearing of the plate**: If the force is too large, the plate may fail in tension along the row. The maximum force allowed in this case is

$$P=St(p-d)t$$

Where St = allowable tensile stress of the plate material.

p = pitch

d = diameter of the rivet hole

t = thickness of the plate

b) **Shearing of the rivet:** The rivet may shear. The maximum force withstood by the joint to prevent this failure is

$Ps = Ss\ \pi/4 \times d^2$ = for lap joint, single strap butt joint

where Ss =allowable shear stress of the rivet material

c) **Crushing of rivet:** If the bearing stress on the rivet is too large the contact surface between the rivet and the plate may get damaged. With a simple assumption of uniform contact stress the maximum force allowed is .

$P = s\ dt$

Where s =allowable bearing stress between the rivet and plate material.

e) **Tearing of the plate at edge:** If the margin is too small, the plate may fail. To prevent the failure a minimum margin of m =1.5d is usually provided.

3. **Efficiency**: Efficiency of the single riveted joint can be obtained as ratio between the maximum of , and and the load carried by a solid plate which is . Thus P1 P2 P3 t s pt

Efficiency = Minimum P1 P2 P3/strength of solid plate

Design of rivet joints:The design parameters in a riveted joints are d , p and m Diameter of the hole (d): When thickness of the plate (t) is more than 8 mm, Unwin’s formula is used

$d = 6\sqrt{t}$ mm.

Otherwise is obtained by equating crushing strength to the shear strength of the joint. In a double riveted zigzag joint, this implies

St= $\prod$ /4d Ss (valid for t < 8 mm)

Q. 1. Two plates of 7 mm thickness are connected by a double riveted lap joint of zigzag pattern. Calculate rivet diameter, rivet pitch and distance between rows of rivets for the joint. Assume 90MPa t s = , 60 MPa s s = , 120MPa . c s =

Ans. Since , the diameter of the rivet hole is selected equating shear strength to the crushing strength, i.e.,

$$2\ \{\pi/4\times d^2\}\ Ss = 2dt.Sc$$

yielding . According to IS code, the standard size is and the corresponding rivet diameter is 18 . d =17.8mm d =19 mm mm Pitch is obtained from the following

$$St(p-d)t = 2\ \{\pi/4\times d^2\}\ Ss \text{ (where d =19 mm)}$$

P= = 54+19=73mm

[Note: If the joint is to comply with I.B.R. specification, then ,Pmax = ct+ 41.28mm where is a constant depending upon the type of joint and is tabulated in the code.]

The distance between the two rivet rows is

$$Pd = P/3+2/3\times d = 37$$

Weld and bolted connection

Bolts and bolting

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.

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 andfitted 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.High Strength Friction Grip bolts (HSFG) provide extremely efficient connections and perform well under fluctuating/fatigue load conditions. These bolts should betightened 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.

Welding and welded connections

Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both

Fundamentals of welding

A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond.

Welding process

In general, gas and arc welding are employed; but, almost all structural welding is arc welding.

In gas welding a mixture of oxygen and some suitable gas is burned at the tip of a torch held in the welder's hand or by an automatic machine. Acetylene is the gas used in structural welding and the process is called oxyacetylene welding.Gas welding is a simple and inexpensive process. But, the process is slow compared to other means of welding. It is generally used for repair and maintenance work.

A temperature of 33000 C to 55000 C is produced in the arc. The welding rod is connected to one terminal of the current source and the object to be welded to the other. In arc welding, fusion takes place by the flow of material from the welding rod across the arc without pressure being applied.

In Shielded Metal Arc Welding or SMA, heating is done by means of electric arc between a coated electrode and the material being joined

Advantages of Bolted Connections

- Use of unskilled labour and simple tools
- Noiseless and quick fabrication
- No special equipment/process needed for installation
- Fast progress of work
- Accommodates minor discrepancies in dimensions
- The connection supports loads as soon as the bolts are tightened
- HSFG bolts do not allow any slip between the elements connected, especially in close tolerance holes, thus providing rigid connections.
- Due to the clamping action, load is transmitted by friction only and the bolts are not subjected to shear and bearing.
- Due to the smaller number of bolts, the gusset plate sizes are reduced.
- Deformation is minimized.

Advantages of Welding

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

Disadvantages of Welding Joints

1. Welded joints are more brittle and therefore their fatigue strength is less than the members joined.
2. Due to uneven heating & cooling of the members during the welding, the members may distort resulting in additional stresses.
3. Skilled labor and electricity are required for welding.
4. No provision for expansion and contraction is kept in welded connection & therefore, there is possibility of racks.
5. The inspection of welding work is more difficult and costlier than the riveting work.
6. Defects like internal air pocket, slag inclusion and incomplete penetration are difficult to detect.

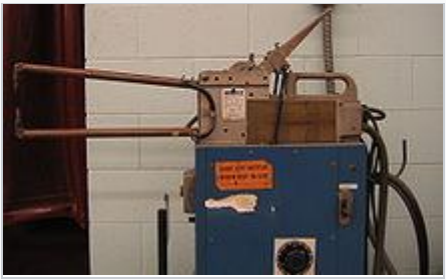
Plug Welding

Plug welding is an alternative to spot welding used by vehicle manufacturers where there is insufficient access for a spot welder. For DIY car restoration it's generally used instead of spot welding on panels flanges that would have originally been spot welded

Start off by drilling 7.5mm holes in the front sheet of metal at a spacing of normally 25mm to 40mm (or whatever the original spot weld spacing was). Then clamp this sheet onto the back sheet.

7.5mm is a reasonably good hole size for 0.8 or 1.0mm sheet. Thicker sheet might require a slightly larger hole size. Try a little test piece out like this one before welding a whole sill onto a car and check the weld has penetrated through both sheets.

Spot welding



Resistance **spot welding** (RSW)[1] is a process in which contacting metal surface points are joined by the heat obtained from resistance to electric current. It is a subset of electric resistance welding.

Q- Find the size and length of the fillet weld for the lap joint to transmit a factored load of 120 KN as shown in Fig. 41. Assume site welds, Fe 410 grade steel and E41 electrode. Assume width of plate as 75 mm and thickness as 8 mm.

Solution-

Minimum size of weld for 8 mm thick section = 3 mm (Table 5, Cl. 10.5.2.3)
Maximum size of weld = 8 – 1.5 = 6.5 mm (Cl. 10.5.8.1)

Choose the size of weld, a = 6 mm

Effective throat thickness = te = 0.70 a = 4.2 mm

Strength of 6 mm weld / mm length = 4.2 x 410 / (√ 3 x 1.5) Cl. 10.5.7.1.1 = 662.7 N/mm

Assuming only two longitudinal welds along the sides Required length of weld = 120 x 103 /662.7 = 181 mm

Length to be provided on each side = 181/2 = 90.5 mm

> 75 mm (width of plate)

Hence, provide 90.5 mm weld on each side with an end return of 2x 6 = 12mm

Overall length of the weld provided = 2 x (90.5 + 2 x 6) = 205 mm

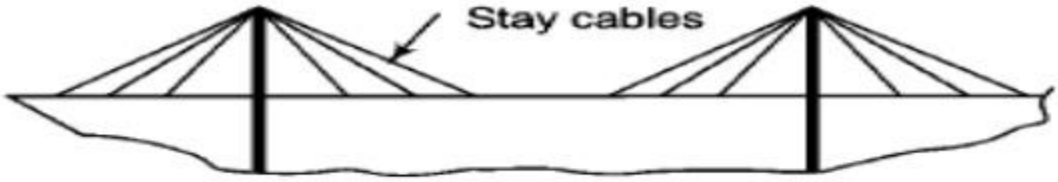
Tension member

Tension members are those which takes only tensile loads. They are usually slender round Steel rods. For example a beam is essentially a tension member.

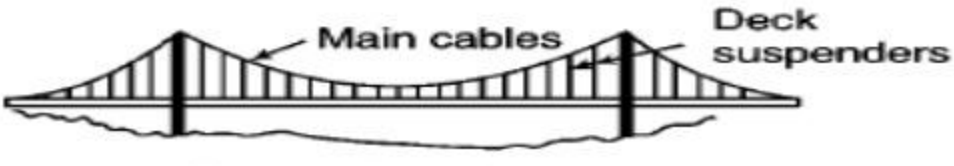
- Net sectional area.
- To maximize the available net area in a bolted connection the bolts are places in a single line. Often the length of the connection necessitates using more than one line.
- In such cases rivets are places in staggered pattern rather than in chain pattern to minimize the reduction of c/s area.

Types of tension members:

1. **Wires and cables**: wires ropes are exclusively used for hoisting purposes and as guy wires in steel stacks and towers. Strands and ropes are formed by helical winding of wires . A strand consists of individual wires wound helically around the central core. These are not recommended in bracing system as they cannot resist compression. The advantages of wire and cable are flexibility and strength.

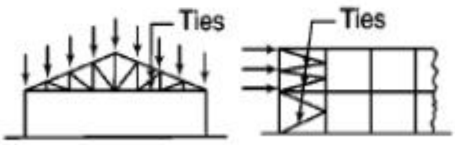


Cable stayed bridges
(c)

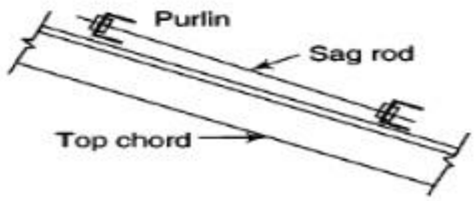


Suspension bridge
(e)

2. **Bars and rods**: These are simplest forms of tension members. Bars and rods are often used as tension members in bracing system, as sag rods to support purlins between trusses. Presently these are not favourite of with the designers because large drift they cause during strong winds and disturbing noise induces by the vibrations.



Single-storey building—roof truss and bracing



Roof-purlin system

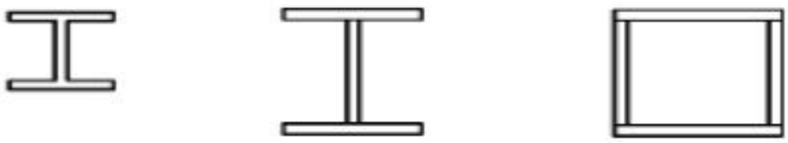
3.Plates and flat bars: These are used often as tension members in transmission towers, foot bridges, etc. These are also used in columns to keep the component members in their correct position. Eg- lacing flats, batten plates, end tie plates etc.

Single and built-up structural shapes:

1. Open sections such as angles, channels and I sections.

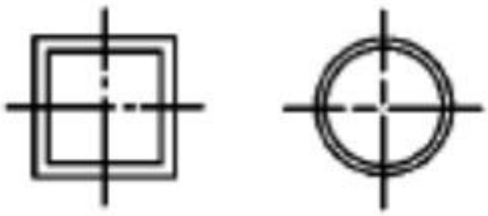
Compound and built-up sections such as double angles and double channels with are without additional plates and jointed with some connection system.

Compound sections



Heavy rolled and built-up sections

- Closed sections such as circular, square, rectangular or hollow sections.



Net sectional area:

- The net sectional area of the tension member is the gross sectional area of the member minus sectional area of the maximum number of holes.

$$A_n = A_g - \text{sectional area of holes}$$

$$A_n = (b - nd_h)t \qquad (1)$$

A_n – net sectional area of the plate

A_g - gross sectional area of the member

b – width of plate

n – number of bolts

d – dia of bolt hole

t – thickness of plate