Unit – I

Various loads and mechanism of the load transfer, partial load factors, structural properties of Steel, Design of structural connections -Bolted, Riveted and Welded connections.

Introduction

Ever since steel began to be used in the construction of structures, it has made possible some of the grandest structures both in the past and also in the present day. Steel is by far the most useful material for building structures with strength of approximately ten times that of concrete, steel is the ideal material for modern construction. Due to its large strength to weight ratio, steel structures tend to be more economical than concrete structures for tall buildings and large span buildings and bridges. Steel structures can be constructed very fast and this enables the structure to be used early thereby leading to overall economy. Steel structures are ductile and robust and can withstand severe loadings such as earthquakes. Steel structures can be easily repaired and retrofitted to carry higher loads. Steel is also a very eco-friendly material and steel structures can be easily dismantled and sold as scrap. Thus the lifecycle cost of steel structures, which includes the cost of construction, maintenance, repair and dismantling, can be less than that for concrete structures. Since steel is produced in the factory under better quality control, steel structures have higher reliability and safety. To get the most benefit out of steel, steel structures should be designed and protected to resist corrosion and fire. They should be designed and detailed for easy fabrication and erection. Good quality control is essential to ensure proper fitting of the various structural elements. The effects of temperature should be considered in design. To prevent development of cracks under fatigue and earthquake loads the connections and in particular the welds should be designed and detailed properly. Special steels and protective measures for corrosion and fire are available and the designer should be familiar with the options available.

A steel structure, like any other, is an assemblage of a group of members which contribute to resist the total load and thereby transfer the loads safely to ground. This consist members subjected to various actions like axial forces (Compression & Tension), bending, shear, torsion e.t.c or a combination of these. The elements are connected together by means of rivets, pins or welds. Depending on the fixity of these joints, the connections are classified as rigid, semi rigid and flexible.

Properties of Structural Steel

The properties of structural steel, as per clause 2.2.4 of IS 800:2007, for use in design, may be taken as given in clauses 2.2.4.1 and 2.2.4.2 of the code.

Physical properties

Physical properties of structural steel, as detailed by cl.2.2.4.1 of IS 800:2007, irrespective of its grade may be taken as: a) Unit mass of steel, p = 7850 kg/m^3 b) Modulus of elasticity, E = 2.0x10^5 N/mm^2 (MPa) c) Poisson ratio, p = 0.3 d) Modulus of rigidity, G = 0.769x10^5 N/mm^2 (MPa) e) Coefficient of thermal expansion c_x.=12x10^{-6}/^{0}C.

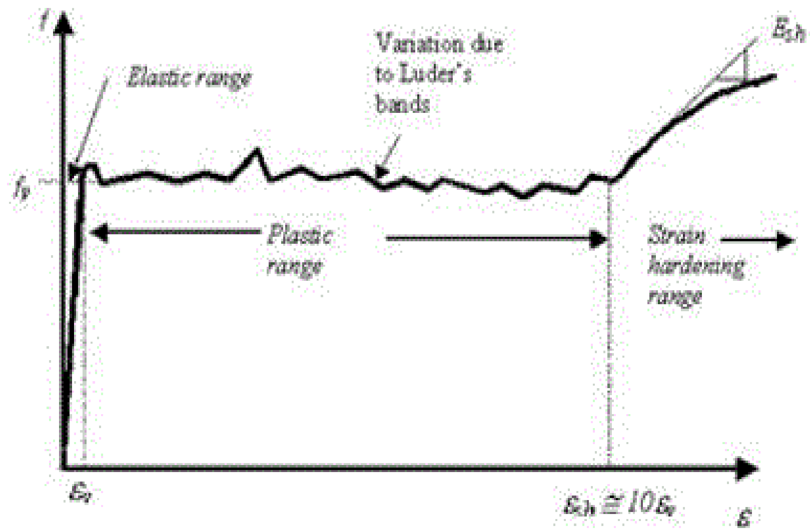
Mechanical properties

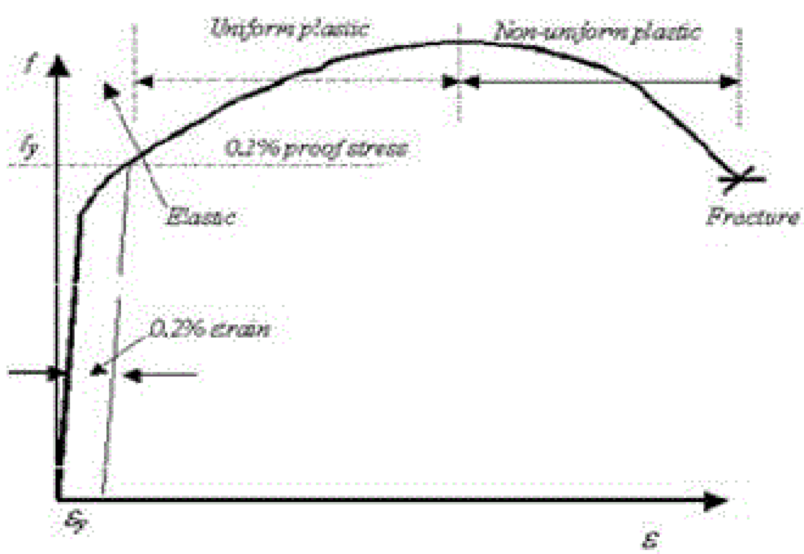
The principal mechanical properties of the structural steel important in design, as detailed by the code IS 800:2007 in cl. 2.2.4.2, are the yield stress, f_y; the tensile or ultimate stress, f_u; the maximum percent elongation on a standard gauge length and notch toughness. Except for notch toughness, the other properties are determined by conducting tensile tests on samples cut from the plates, sections, etc, in accordance with IS 1608. Commonly used properties for the common steel products of different specifications are summarized in Table 1 of IS 800:2007. Highlights of the table are reproduced for ready reference as Table 1.

Table 1. Tensile Properties of Structural Steel Products

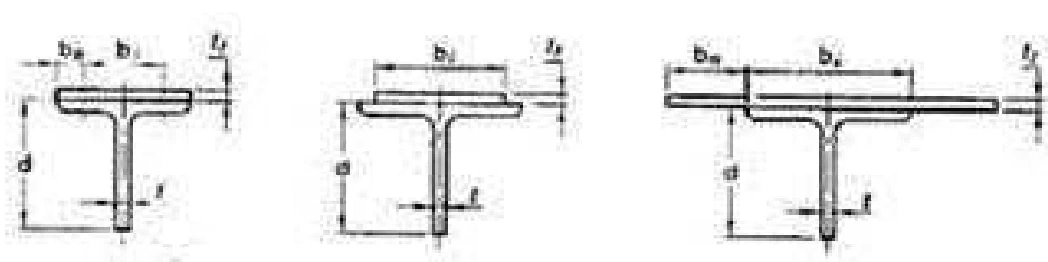
IS Code	Grade	Yield stress (Mpa) min (for d or t)			Ultimate tensile stress (MPa) min	Elongation Percent min
		<20	20 - 40	>40		
IS 2062	E 165 (Fe 290)	165	165	165	290	23
	E250(Fe410W)A	250	240	230	410	23
	E250(Fe 410 W)B	250	240	230	410	23
	E250(Fe 410 W)C	250	240	230	410	23
	E 300 (Fe 440)	300	290	280	440	22
	E 350 (Fe 490)	350	330	320	490	22
	E 410 (Fe 540)	410	390	380	540	20
	E 450 (Fe 570) D	450	430	420	570	20
	E 450 (Fe 590) E	450	430	420	590	20

Stress – Strain Curve





Rolled Steel Sections



COMPOUND ELEMENTS

b_i — Internal Element Width

b_e — External Element Width

General Design Requirements

The general design requirements are outlined in Section 3 of IS 800:2007.

Basis for Design

The bases of the design are given in Section 3.1 of IS 800:2007. It is as follows.

Design Objective

The objective of design, as outlined in Cl.3.1.1 of IS 800:2007, is the achievement of an acceptable probability that structures will perform satisfactorily for the intended purpose during the design life. With an appropriate degree of safety, they should sustain all the loads and deformations, during construction and use and have adequate resistance to certain expected accidental loads and fire. Structure should be stable and have alternate load paths to prevent disproportionate overall collapse under accidental loading.

Methods of Design

Method of Design of steel structures is given in Cl. 3.1.2 of IS 800:2007. In the previous version of the code, the design of steel structures was essentially using Working Stress Method. But IS 800:2007 permits us to design the structure to satisfy the various Limit States. It also advocates the use of Working Stress Method only to the situations where Limit State cannot be conveniently employed. As per Cl. 3.1.2.1 of IS 800:2007, Structure and its elements shall normally, be designed by the limit state method. Account should be taken of accepted theories, experimental information and experience and the need to design for durability. This clause admits that calculations alone may not produce Safe, serviceable and durable structures. Suitable materials, quality control, adequate detailing and good supervision are equally important. As per Cl. 3.1.2.2 of IS 800:2007, where the limit states method cannot be conveniently adopted; the working stress design (Section 11 of IS 800:2007) may be used.

Loads and Forces

Clause 3.2 of IS 800:2007 specifies the various loads and forces that has to be considered while performing the design of steel structures. As per Cl. 3.2.1 of IS 800:2007, for the purpose of designing any element, member or a structure, the following loads (actions) and their effects shall be taken into account, where applicable, with partial safety factors and combinations (Cl. 5.3.3 of IS 800:2007). (a) Dead loads; (b) Imposed loads (live load, crane load, snow load, dust load, wave load, earth pressures, etc); (c) Wind loads; (d) Earthquake loads; (e) Erection loads; (f) Accidental loads such as those due to blast, impact of vehicles, etc; and (g) Secondary effects due to contraction or expansion resulting from temperature changes, differential settlements of the structure as a whole or of its components, eccentric.

Load Combinations

Combination	Limit State of Strength					Limit State of Serviceability			
	DL	LL[1)]		WL/EL	AL	DL	LL[1)]		WL/EL
		Leading	Accompanying				Leading	Accompanying	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DL+LL+CL	1.5	1.5	1.05	—	—	1.0	1.0	1.0	—
DL+LL+CL+	1.2	1.2	1.05	0.6	—	1.0	0.8	0.8	0.8
WL/EL	1.2	1.2	0.53	1.2					
DL+WL/EL	1.5 (0.9)[b]	—	—	1.5	—	1.0	—	—	1.0
DL+ER	1.2 (0.9)[b]	1.2	—	—	—	—	—	—	—
DL+LL+AL	1.0	0.35	0.35	—	1.0	—	—	—	—

Member	Maximum Effective Slenderness Ratio (KL/r)
A member carrying compressive loads resulting from dead loads and imposed loads	180
A tension member in which a reversal of direct stress occurs due to loads other than wind or seismic forces	180
A member subjected to compression forces resulting only from combination with wind/earthquake actions, provided the deformation of such member does not adversely affect tbe stress in any part of the structure	250
Compression flange of a beam against lateral torsional buckling	300
A member normally acting m a tie in a roof truss or a bracing system not considered effective when subject to possible reversal of stress into	350
compression resulting from the action of wind or earthquake forces Members always under tension (other than pre-tensioned members)	400

Classification of Cross-Sections

Plate elements of a cross-section may buckle locally due to compressive stresses. The local buckling can be avoided before the limit state is achieved by limiting the width to thickness ratio of each element of a cross-section subjected to compression due to axial force, moment or shear. When plastic analysis is used, the members shall be capable of forming plastic hinges with sufficient rotation capacity (ductility) without local buckling, to enable the redistribution of bending moment required before formation of the failure mechanism. When elastic analysis is used, the member shall be capable of developing the yield stress under compression without local buckling. On basis of the above, Cl. 3.7 of IS 800:200 categorizes the sections in to four classes as follows.

When different elements of a cross-section fall under different classes, the section shall be classified as governed by the most critical element. The maximum value of limiting width to thickness ratios of elements for different classifications of sections are given in Table 2 of IS 800:2007 which is reproduced here as Table 3.

Class 1 (Plastic)

Cross-sections which can develop plastic hinges and have the rotation capacity required for failure of the structure by formation of plastic mechanism fall under this category. The width to thickness ratio of plate elements shall be less than that specified under Class 1 (Plastic), in Table 2 of IS 800:2007.

Class 2 (Compact)

Cross-sections which can develop plastic moment of resistance, but have inadequate plastic hinge rotation capacity for formation of plastic mechanism, due to local buckling come under this class. The width to thickness ratio of plate elements shall be less than that specified under Class 2 (Compact), but greater than that specified under Class 1 (Plastic), in Table 2 of IS 800:2007.

Class 3 (Semi-compact)

Cross-sections in which the extreme fiber in compression can reach yield stress but cannot develop the plastic moment of resistance, due to local buckling. The width to thickness ratio of plate elements shall be less than that specified under Class 3 (Semi-compact), but greater than that specified under Class 2 (Compact), in Table 2 of IS 800:2007.

Compression Element			Ratio	Class of Section		
				Class 1 Plastic	Class 2 Compact	Class 3 Semi-compact
(1)			(2)	(3)	(4)	(5)
Outstanding element of compression flange	Rolled section		b/t_f	9.4ε	10.5ε	15.7ε
	Welded section		b/t_f	8.4ε	9.4ε	13.6ε
Internal element of compression flange	Compression due to bending		b/t_f	29.3ε	33.5ε	42ε
	Axial compression		b/t_f	Not applicable		
Web of an I, H or box section	Neutral axis at mid-depth		d/t_w	84ε	105ε	126ε
	Generally	If r_1 is negative:	d/t_w	$\frac{84\varepsilon}{1+r_1}$ but $\leq 42\varepsilon$	$\frac{105.0\varepsilon}{1+r_1}$	$\frac{126.0\varepsilon}{1+2r_1}$ but $\leq 42\varepsilon$
		If r_1 is positive:	d/t_w		$\frac{105.0\varepsilon}{1+1.5r_1}$ but $\leq 42\varepsilon$	
	Axial compression		d/t_w	Not applicable		42ε
Web of a channel			d/t_w	42ε	42ε	42ε
Angle, compression due to bending (Both criteria should be satisfied)			b/t d/t	9.4ε 9.4ε	10.5ε 10.5ε	15.7ε 15.7ε
Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)			b/t d/t $(b+d)/t$	Not applicable		15.7ε 15.7ε 25ε
Outstanding leg of an angle in contact back-to-back in a double angle member			d/t	9.4ε	10.5ε	15.7ε
Outstanding leg of an angle with its back in continuous contact with another component			d/t	9.4ε	10.5ε	15.7ε
Stem of a T-section, rolled or cut from a rolled I or H-section			D/t_f	8.4ε	9.4ε	18.9ε
Circular hollow tube, including welded tube subjected to: a) moment			D/t	$42\varepsilon^2$	$52\varepsilon^2$	$146\varepsilon^2$
b) axial compression			D/t	Not applicable		$88\varepsilon^2$

Limit State Design

The current revision of the code of practice, IS 800:2000, recommends limit state method for design of structures using hot rolled sections. This method is outlined in section 5 of IS 800:2007. However, it retained working stress method of design which was the design method for decades. But the scope of the working stress method is limited to those situations where limit state method cannot be conveniently employed.

Basis for Design

In the limit state design method, the structure shall be designed to withstand safely all loads likely to act on it throughout its life. It shall not suffer total collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent beyond the local damages. The objective of the design is to achieve a structure that will remain fit for use during its life with acceptable target reliability. In other words, the probability of a limit state being reached during its lifetime should be very low. The acceptable limit for the safety and serviceability requirements before failure occurs is called a limit state. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

Steel structures are to be designed and constructed to satisfy the design requirements with regard to stability, strength, serviceability, brittle fracture, fatigue, fire, and durability such that they meet the following: a) Remain fit with adequate reliability and be able to sustain all actions (loads) and other influences experienced during construction and use; b) Have adequate durability under normal maintenance; c) Do not suffer overall damage or collapse disproportionately under accidental events like explosions, vehicle impact or due to consequences of human error to an extent beyond local damage. The potential for catastrophic damage shall be limited or avoided by appropriate choice of one or more of the following:

- Avoiding, eliminating or reducing exposure to hazards, which the structure is likely to sustain.
- Choosing structural forms, layouts and details and designing such that: i) the structure has low sensitivity to hazardous conditions; and ii) the structure survives with only local damage even after serious damage to any one individual element by the hazard.
- Choosing suitable material, design and detailing procedure, construction specifications, and control procedures for shop fabrication and field construction as relevant to the particular structure.

The following conditions may be satisfied to avoid a disproportionate collapse: The building should be effectively tied together at each principal floor level and each column should be effectively held in position by means of continuous ties (beams) nearly orthogonal, except where the steel work supports only cladding weighing not more than 0.7 kN/m^2 along with imposed and wind loads. These ties must be steel members such as beams, which may be designed for other purposes, steel bar reinforcement anchoring the steel frame to concrete floor or steel mesh reinforcement in composite slab with steel profiled sheeting directly connected to beam with shear connectors. These steel ties and their end connections should be capable of resisting factored tensile force not less than the factored dead and imposed loads acting on the floor area tributary to the tie nor less than 75 kN, Such connection of ties to edge column should also be capable of resisting 1 percent of the maximum axial compression in the column at the level due to factored dead and imposed loads. All column splices should be capable of resisting a tensile force equal to the largest of a factored dead and live load reaction from a single floor level located between that column splice and the next column splice below that splice. Lateral load system to resist notional horizontal loads prescribed in Cl. 4.3.6 of IS 800:2007 should be distributed throughout the building in nearly orthogonal directions so that no substantial portion is connected at only one point to such a system. Precast concrete or other heavy floor or roof units should be effectively anchored in the direction of their span either to each other over the support or directly to the support. Where the above conditions to tie the columns to the floor adequately are not satisfied each storey of the building should be checked to ensure that disproportionate collapse would not precipitate by the notional removal, one at a time, of each column. Where each floor is not laterally supported by more than one system, check should be made at each storey by removing one such lateral support system at a time to ensure that disproportionate collapse would not occur. The collapse is considered disproportionate, if more than 15 percent of the floor or roof area of 70 m^2

collapse at that level and at one adjoining level either above or below it, under a load equal to 1.05 or 0.9 times the dead load, 0.33 times temporary or full imposed load of permanent nature (as in storage buildings) and 0.33 times wind load acting together.

Design of Connections

Section 10 of IS 800:2007 deals with the design and detailing requirements for joints between members. The connections in a structure shall be designed so as to be consistent with the assumptions made in the analysis of the structure and comply with the requirements specified in section 10 of the code.

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 behavior of connections is quite complex due to geometric imperfections and complexities, lack of fit, residual stresses etc; making it complex to analyses. 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. This is outlined in Cl. 10.1.4 of IS 800:2007.

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.

1. Classification based on the connector

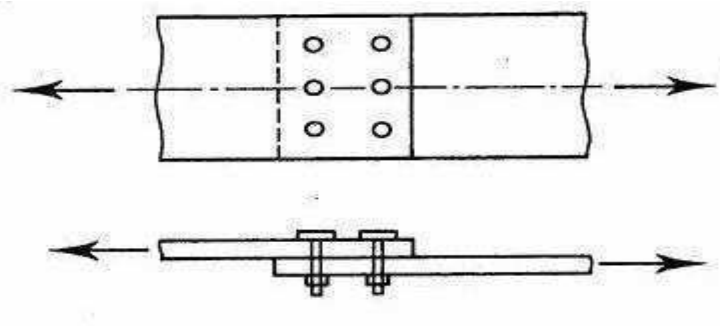
   Connections are classified based on the connecting element in to (a) Riveted, (b) Bolted, (c) Pinned and (d) Welded connection. Of these riveted, bolted and pinned connections behave in a similar manner.

2. Classification based on the fixity of the joint

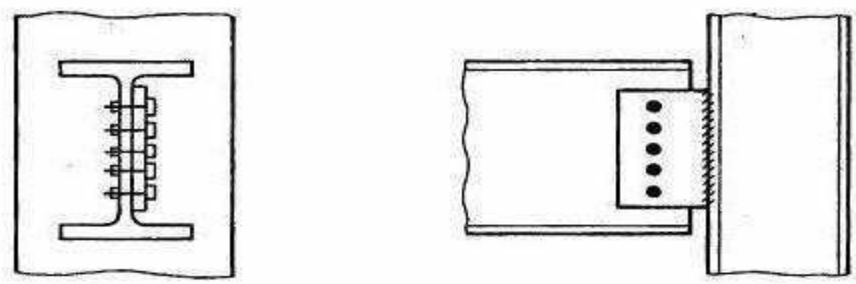
   Based on the fixity of the joint, connections are classified in to (a) Rigid joint, (b) Semi rigid joint and (c) Flexible joints.

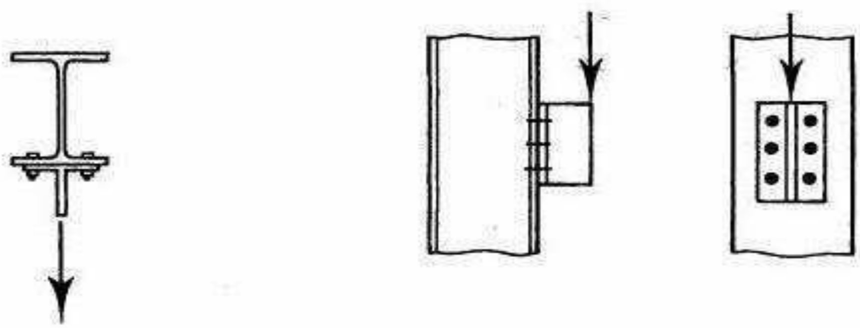
Bolted Connection

- There are different types of bolted connections. They can be categorized based on the type of loading.
- Tension member connection and splice. It subjects the bolts to forces that tend to shear the shank.
- Beam end simple connection. It subjects the bolts to forces that tend to shear the shank. - Hanger connection. The hanger connection puts the bolts in tension



(a)





(d) (e)

- The bolts are subjected to shear or tension loading.
- In most bolted connection, the bolts are subjected to shear.
- Bolts can fail in shear or in tension.
- You can calculate the shear strength or the tensile strength of a bolt
- Simple connection: If the line of action of the force acting on the connection passes through the center of gravity of the connection, then each bolt can be assumed to resist an equal share of the load.
- The strength of the simple connection will be equal to the sum of the strengths of the individual bolts in the connection.

- We will first concentrate on bolted shear connections.

Bolted Shear Connections

- We want to design the bolted shear connections so that the factored design strength ($\phi\ R_n$) is greater than or equal to the factored load.
- So, we need to examine the various possible failure modes and calculate the corresponding design strengths.
- Possible failure modes are:

  - Shear failure of the bolts

  - Failure of member being connected due to fracture or block shear or ….

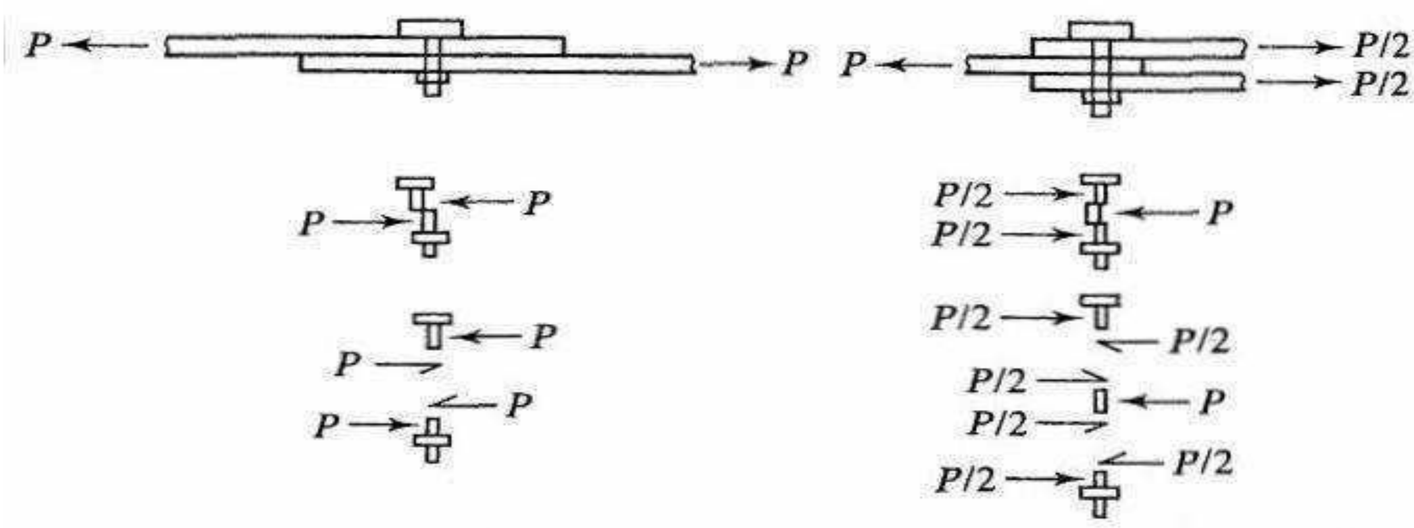
  - Edge tearing or fracture of the connected plate

  - Tearing or fracture of the connected plate between two bolt holes

  - Excessive bearing deformation at the bolt hole

- Shear failure of bolts
- Average shearing stress in the bolt = $f_v = P/A = P/(\pi\ d_b^2/4)$
- P is the load acting on an individual bolt
- A is the area of the bolt and d_b is its diameter
- Strength of the bolt = $P = f_v \times (\pi\ d_b^2/4)$ where f_v = shear yield stress = $0.6F_y$ - Bolts can be in *single* shear or *double* shear as shown below.
- When the bolt is in double shear, two cross-sections are effective in resisting the load.

The bolt in *double shear* will have the twice the shear strength of a bolt in single shear.

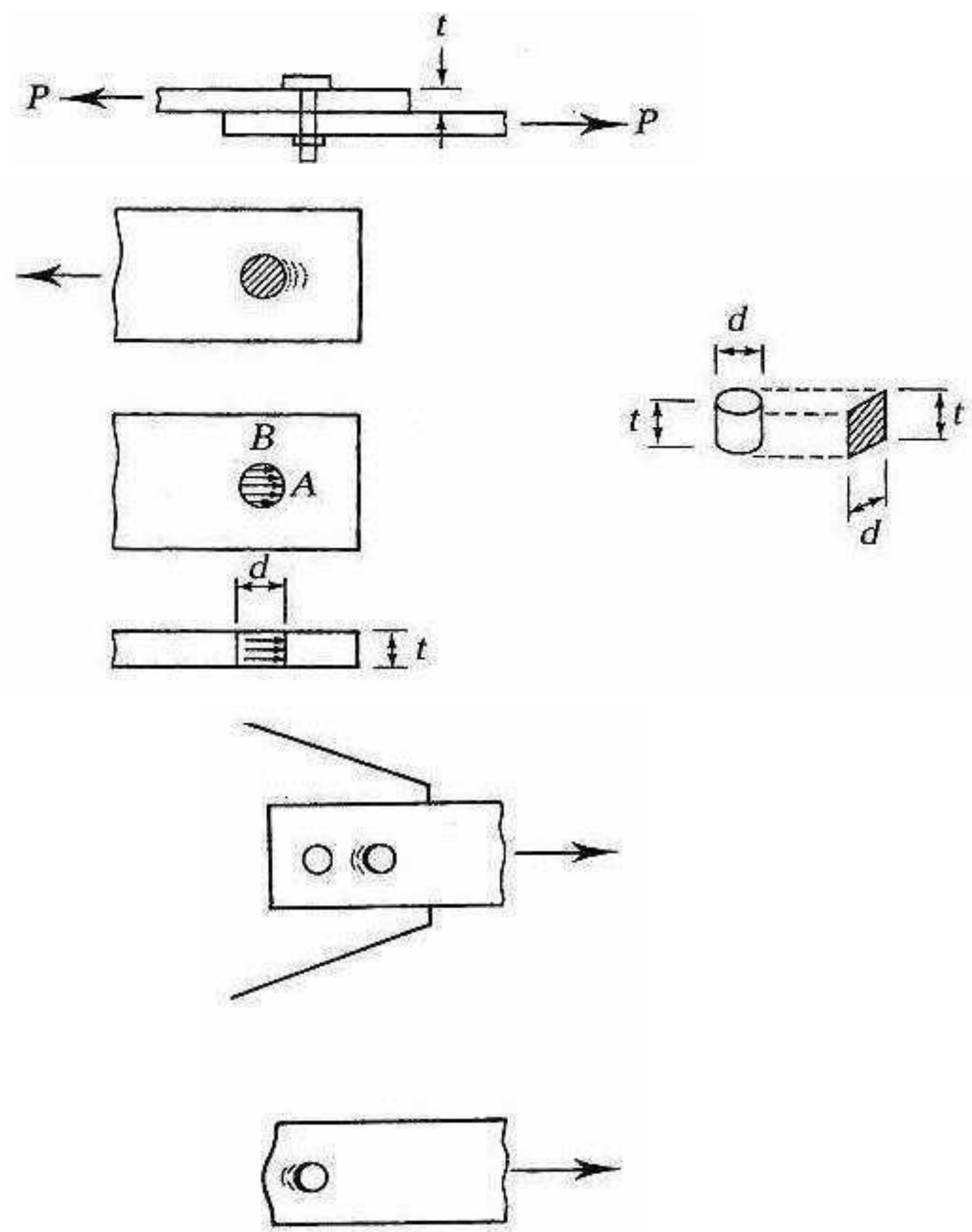


(a) Single Shear (b) Double Shear

- **Failure of connected member**
- **We have covered this in detail in Ch. 2 on tension members - Member can fail due to tension fracture or block shear.**
- **Bearing failure of connected/connecting part due to bearing from bolt holes**
- **Hole is slightly larger than the fastener and the fastener is loosely placed in hole**
- **Contact between the fastener and the connected part over approximately half the circumference of the fastener**
- **As such the stress will be highest at the radial contact point (A). However, the average stress can be calculated as the applied force divided by the projected area of contact**
- **Average bearing stress $f_p = P/(d_b\,t)$, where P is the force applied to the fastener.**
- **The bearing stress state can be complicated by the presence of nearby bolt or edge. The bolt spacing and edge distance will have an effect on the bearing stress.**
- **Bearing stress effects are independent of the bolt type because the bearing stress acts on the connected plate not the bolt.**

- A possible failure mode resulting from excessive bearing close to the edge of the connected element is shear tear-out as shown below. This type of shear tear-out can also occur between two holes in the direction of the bearing load.

$$R_n = 2 \times 0.6\ F_u\ L_c\ t = 1.2\ F_u\ L_c\ t$$



- To prevent excessive deformation of the hole, an upper limit is placed on the bearing load. This upper limit is proportional to the fracture stress times the projected bearing area

$$R_n = C \times F_u \times \text{bearing area} = C\ F_u\ d_b\ t$$

If deformation is not a concern then C = 3, If deformation is a concern then C=2.4 C = 2.4 corresponds to a deformation of 0.25 in.

- Finally, the equation for the bearing strength of a single bolts is ϕR_n

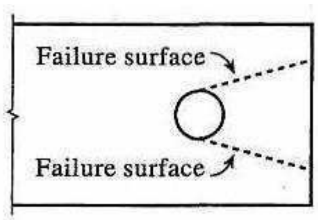
$$\text{Where, } \phi = 0.75 \text{ and } R_n = 1.2\, L_c\, t\, F_u < 2.4\, d_b\, t\, F_u$$

L_c is the clear distance in the load direction, from the edge of the bolt hole to the edge of the adjacent hole or to the edge of the material. This relationship can be simplified as follows:

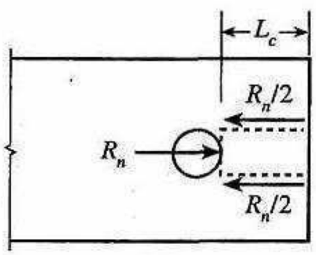
The upper limit will become effective when $1.2\, L_c\, t\, F_u = 2.4\, d_b\, t\, F_u$ i.e., the upper limit will become effective when $L_c = 2\, d_b$

$$\text{If } L_c < 2\, d_b,\quad R_n = 1.2\, L_c\, t\, F_u$$

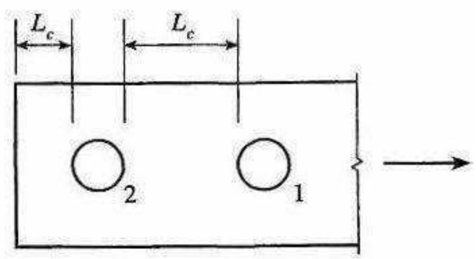
$$\text{If } L_c > 2\, d_b,\quad R_n = 1.4\, d_b\, t\, F_u$$



(a)

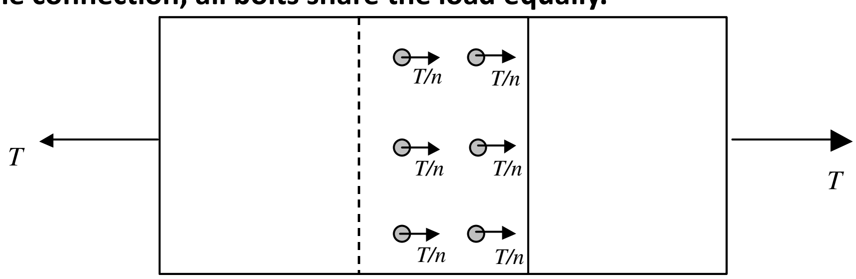


(b)

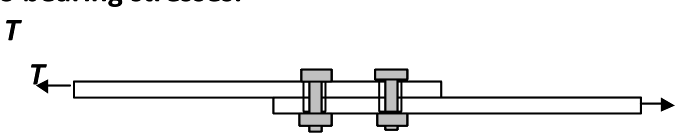


Design Provisions for Bolted Shear Connections

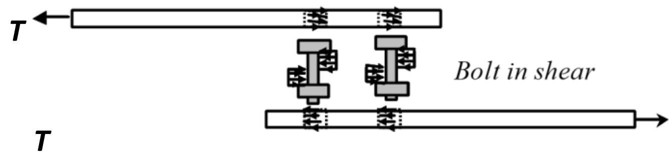
- In a simple connection, all bolts share the load equally.



- In a bolted shear connection, *the bolts are subjected to shear* and the connecting / connected plates are subjected to bearing stresses.



Bearing stresses in plate



Bearing stresses in plate

- The shear strength of all bolts = shear strength of one bolt x number of bolts
- The bearing strength of the connecting / connected plates can be calculated using equations given by AISC specifications.
- The tension strength of the connecting / connected plates can be calculated as discussed earlier in Chapter 2.

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. It is distinguished from other forms of mechanical connections, such as riveting or bolting, which are formed by friction or mechanical interlocking. It is one of the oldest and reliable methods of joining. Welding offers many advantages over bolting and riveting. Welding enables direct transfer of stress between members eliminating gusset and splice plates necessary for bolted structures. Hence, the weight of the joint is minimum. In the case of tension members, the absence of holes improves the efficiency of the section. It involves less fabrication cost compared to other methods due to handling of fewer parts and elimination of operations like drilling, punching etc. and consequently less labour leading to economy. Welding offers air tight and water tight joining and hence is ideal for oil storage tanks, ships etc. Welded structures also have a neat appearance and enable the connection of complicated shapes. Welded structures are more rigid compared to structures with riveted and bolted connections. A truly continuous structure is formed by the process of fusing the members together. Generally welded joints are as strong as or stronger than the base metal, thereby placing no restriction on the joints. Stress concentration effect is also considerably less in a welded connection. Some of the disadvantages of welding are that it requires skilled manpower for welding as well as inspection. Also, non-destructive evaluation may have to be carried out to detect defects in welds. Welding in the field may be difficult due to the location or environment. Welded joints are highly prone to cracking under fatigue loading. Large residual stresses and distortion are developed in welded connections.

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. The tendency of atoms to bond is the fundamental basis of welding. The inter-diffusion between the materials that are joined is the underlying principle in all welding processes. The diffusion may take place in the liquid, solid or mixed state. In welding the metallic materials are joined by the formation of metallic bonds and a perfect connection is formed. In practice however, it is very difficult to achieve a perfect joint; for, real surfaces are never smooth. When welding, contact is established only at a few points in the surface, joins irregular surfaces where atomic bonding occurs. Therefore the strength attained will be only a fraction of the full strength. Also, the irregular surface may not be very clean, being contaminated with adsorbed moisture, oxide film, grease layer etc. In the welding of such surfaces, the contaminants have to be removed for the bonding of the surface atoms to take place. This can be accomplished by applying either heat or pressure. In practical welding, both heat and pressure are applied to get a good joint. As pointed out earlier, any welding process needs some form of energy, often heat, to connect the two materials.

The relative amount of heat and pressure required to join two materials may vary considerably between two extreme cases in which either heat or pressure alone is applied. When heat alone is applied to make the joint, pressure is used merely to keep the joining members together. Examples of such a process are Gas Tungsten Arc Welding (GTAW), Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW) etc. On the other hand pressure alone is used to make the bonding by plastic deformation, examples being cold welding, roll welding, ultrasonic welding etc. There are other welding methods where both pressure and heat are employed, such as resistance welding, friction welding etc. A flame, an arc or resistance to an electric current, produces the required heat. Electric arc is by far the most popular source of heat used in commercial welding practice.

Types of joints and welds

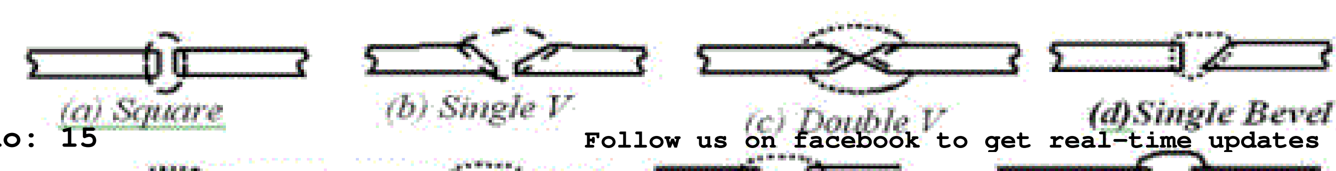
By means of welding, it is possible to make continuous, load bearing joints between the members of a structure. A variety of joints is used in structural steel work and they can be classified into four basic configurations namely, Lap joint, Tee joint, Butt joint and Corner joint.

For lap joints, the ends of two members are overlapped and for butt joints, the two members are placed end to end. The T- joints form a Tee and in Corner joints, the ends are joined like the letter L. Most common joints are made up of fillet weld or the butt (also calling groove) weld. Plug and slot welds are not generally used in structural steel work. Fig. Fillet welds are suitable for lap joints and Tee joints and groove welds for butt and corner joints. Butt welds can be of complete penetration or incomplete penetration depending upon whether the penetration is complete through the thickness or partial. Generally a description of welded joints requires an indication of the type of both the joint and the weld.

Though fillet welds are weaker than butt welds, about 80% of the connections are made with fillet welds. The reason for the wider use of fillet welds is that in the case of fillet welds, when members are lapped over each other, large tolerances are allowed in erection. For butt welds, the members to be connected have to fit perfectly when they are lined up for welding. Further butt welding requires the shaping of the surfaces to be joined as shown in Fig. To ensure full penetration and a sound weld, a backup plate is temporarily provided as shown in Fig.

Butt welds

Full penetration butt welds are formed when the parts are connected together within the thickness of the parent metal. For thin parts, it is possible to achieve full penetration of the weld. For thicker parts, edge preparation may have to be done to achieve the welding. There are nine different types of butt joints: square, single V, double V, and single U, double U, single J, double J, single bevel and double bevel.



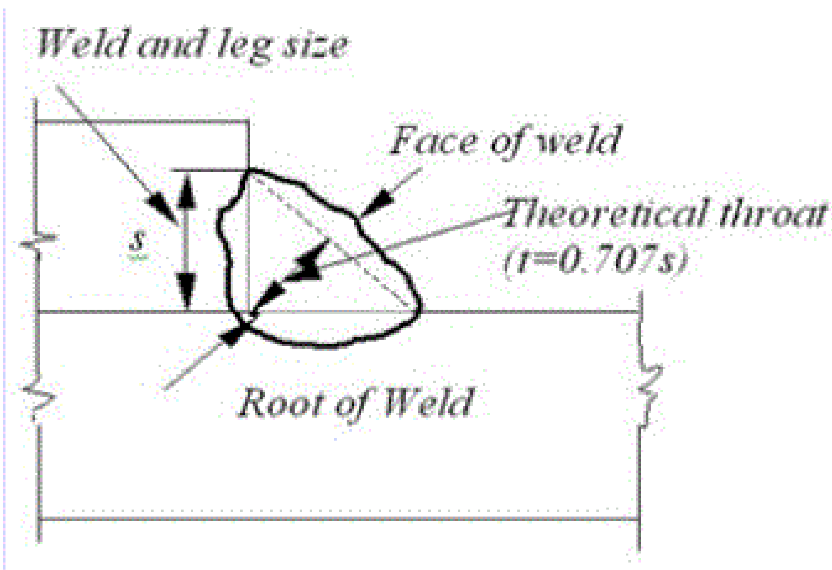
Different types of butt welds

The main use of butt welds is to connect structural members, which are in the same plane. A few of the many different butt welds are shown in Fig. 3.16.There are many variations of butt welds and each is classified according to its particular shape. Each type of butt weld requires a specific edge preparation and is named accordingly. The proper selection of a particular type depends upon: Size of the plate to be joined; welding is by hand or automatic; type of welding equipment, whether both sides are accessible and the position of the weld.

Butt welds have high strength, high resistance to impact and cyclic stress. They are most direct joints and introduce least eccentricity in the joint. But their major disadvantages are: high residual stresses, necessity of edge preparation and proper aligning of the members in the field. Therefore, field butt joints are rarely used.

Fillet welds

Owing to their economy, ease of fabrication and adaptability, fillet welds are widely used. They require less precision in the fitting up because the plates being joined can be moved about more than the Butt welds. Another advantage of fillet welds is that special preparation of edges, as required by Butt welds, is not required. In a fillet weld the stress condition in the weld is quite different from that of the connected parts. A typical fillet weld is shown in Fig.



Typical fillet weld

The root of the weld is the point where the faces of the metallic members meet. The theoretical throat of a weld is the shortest distance from the root to the hypotenuse of the triangle. The throat area equals the theoretical throat distance times the length of the weld.

The concave shape of free surface provides a smoother transition between the connected parts and hence causes less stress concentration than a convex surface. But it is more vulnerable to shrinkage and cracking than the convex surface and has a much reduced throat area to transfer stresses. On the other hand, convex shapes provide extra weld metal or reinforcement for the throat. For statically loaded structures, a slightly convex shape is preferable, while for fatigue – prone structures, concave surface is desirable.

Large welds are invariably made up of a number of layers or passes. For reasons of economy, it is desirable to choose weld sizes that can be made in a single pass. Large welds scan be made in a single pass by an automatic machine, though manually, 8 mm fillet is the largest single-pass layer.