DESIGN OF STEEL STRUCTURES-I

Introduction to Limit State Design

- A Civil Engineering Designer has to ensure that the structures and facilities he designs are (i) fit for their purpose (ii) safe and (iii) economical and durable.
- Thus safety is one of the paramount responsibilities of the designer. However, it is difficult to assess at the design stage how safe a proposed design will actually be. There is, in fact, a great deal of uncertainty about the many factors, which influence both safety and economy. The uncertainties affecting the safety of a structure are due to

➢ Uncertainty about loading

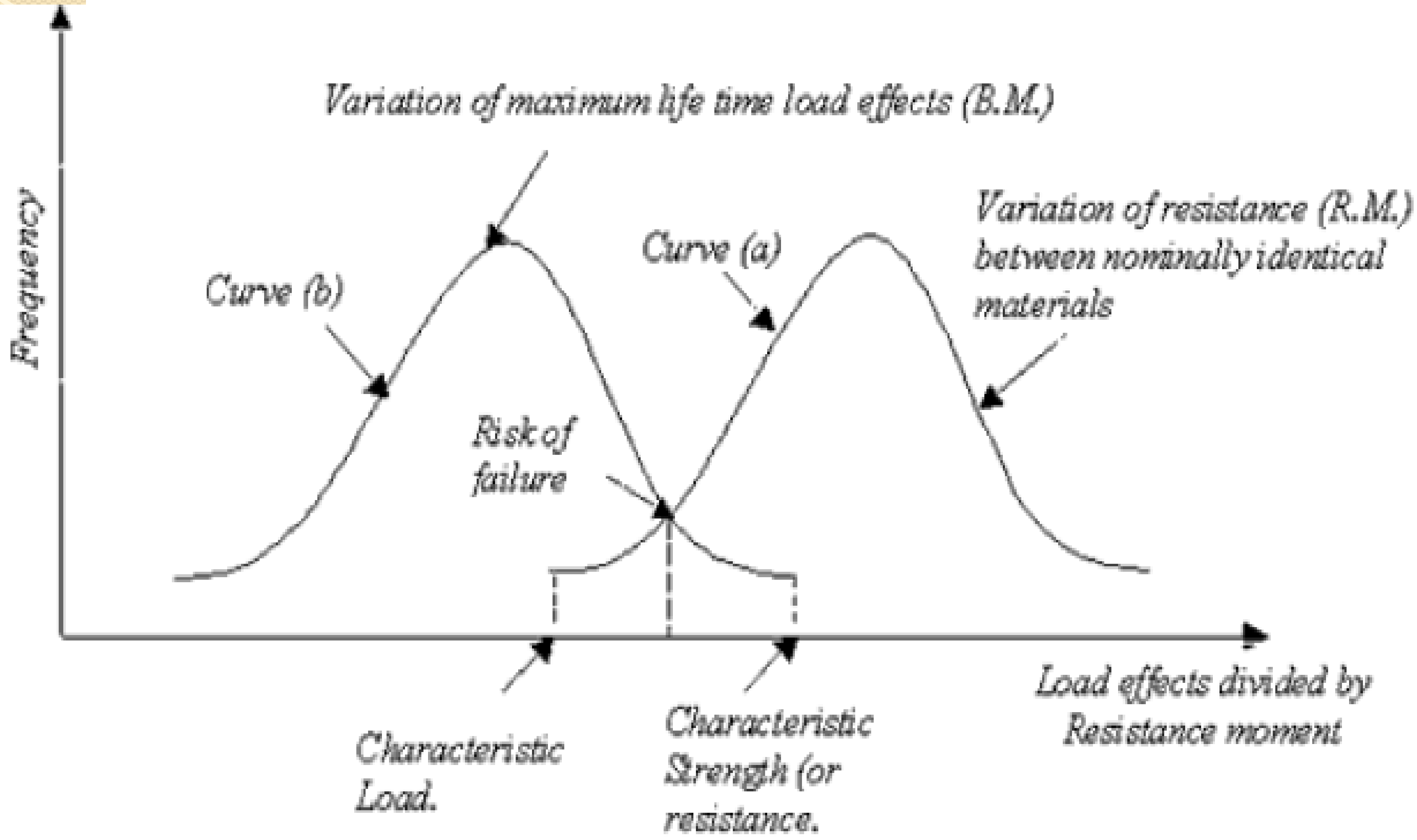
➢ Uncertainty about material strength and

➢ Uncertainty about structural dimensions and behavior.

- These uncertainties together make it impossible for a designer to guarantee that a structure will be absolutely safe. All that the designer can ensure is that the risk of failure is extremely small, despite the uncertainties.
- ***The uncertainty here is both due to variability of the loads applied to the structure, and also due to the variability of the load distribution through the structure.***
- *Thus, if a* particularly weak structural component is subjected to a heavy load which exceeds the strength of the structural component, clearly failure could occur.
- Unfortunately it is not practicable to define the probability distributions of loads and strengths, as it will involve hundreds of tests on samples of components.
- Normal design calculations are made using a single value for each load and for each material property and taking an appropriate safety factor in the design calculations. The single value used is termed as ***"Characteristic Strength or Resistance" and "Characteristic Load".***

- ***Characteristic resistance of a material (such as Concrete or Steel) is defined as that value of resistance below which not more than a prescribed percentage of test results may be expected to fall. (For example the characteristic*** yield stress of steel is usually defined as that value of yield stress below which not more than 5% of the test values may be expected to fall). In other words, this strength is expected to be exceeded by 95% of the cases.
- Similarly, ***the characteristic load is that value of the load, which has an accepted probability of not being exceeded during the life span of the structure .*** Characteristic load is therefore that load which will not be exceeded 95% of the time.

Statistical meaning of safety

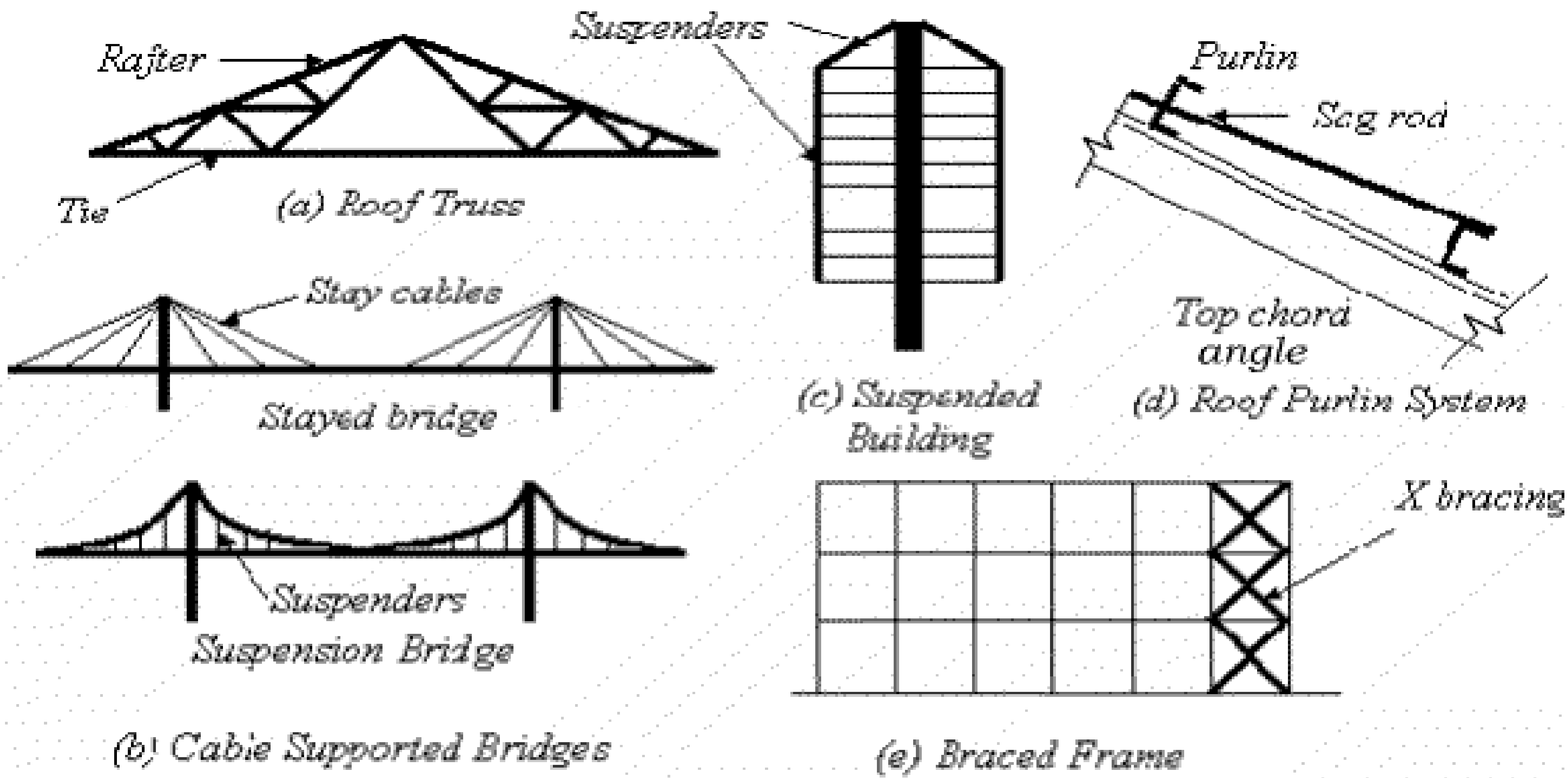


Design of Tension Members

Introduction

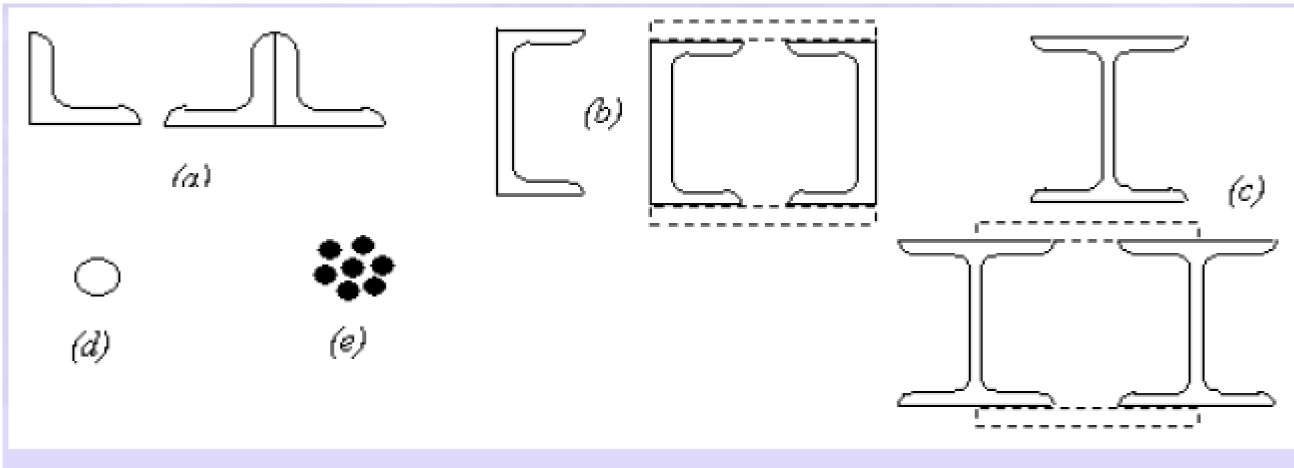
- Tension members are linear members in which axial forces act so as to elongate (stretch) the member. A rope, for example, is a tension member.
- Tension members carry loads most efficiently, since the entire cross section is subjected to uniform stress.
- Unlike compression members, they do not fail by buckling (see chapter on compression members).
- Ties of trusses [Fig 1(a)], suspenders of cable stayed and suspension bridges [Fig.1(b)], suspenders of buildings systems hung from a central core [Fig.1(c)] (such buildings are used in earthquake prone zones as a way of minimizing inertia forces on the structure), and sag rods of roof purlins [Fig 1(d)] are other examples of tension members

Examples of Tension members in structures



- Tension members are also encountered as bracings used for the lateral load resistance. In X type bracings [Fig 1(e)] the member which is under tension, due to lateral load acting in one direction, undergoes compressive force, when the direction of the lateral load is changed and vice versa. Hence, such members may have to be designed to resist tensile and compressive forces.
- The tension members can have a variety of cross sections. The single angle and double angle sections [Fig.2 (a)] are used in light roof trusses as in industrial buildings.
- The tension members in bridge trusses are made of channels or I sections, acting individually or built-up [Figs.2(c) and 2(d)]. The circular rods [Fig.2 (d)] are used in bracings designed to resist loads in tension only. They buckle at very low compression and are not considered effective. Steel wire ropes [Fig.2 (e)] are used as suspenders in the cable suspended bridges and as main stays in the cable-stayed bridges.

Cross sections of tension members



Connections

Connections

- Connections form an important part of any structure and are designed more conservatively than members. This is because, connections are more complex than members to analyze , and the discrepancy between analysis and actual behavior is large.
- Further, in case of overloading, we prefer the failure confined to an individual member rather than in connections, which could affect many members.
- Connections account for more than half the cost of structural steelwork and so their design and detailing are of primary importance for the economy of the structure.

Connections

- The type of connection designed has an influence on member design and so must be decided even prior to the design of the structural system and design of members.
- For example, in the design of bolted tension members, the net area is calculated assuming a suitable number and diameter of bolts based on experience.
- Therefore, it is necessary to verify the net area after designing the connection. Similarly in the analysis of frames, the member forces are determined by assuming the connections to be pinned, rigid, or semi-rigid, as the actual behavior cannot be precisely defined.

Connections

- Just as members are classified as bending members or axially loaded members depending on the dominant force/moment resisted, connections are also classified into idealized types while designing.
- But the actual behavior of the connection may be different and this point should always be kept in mind so that the connection designed not differ significantly from the intended type. Take for example, the connection of an axially loaded truss member at a joint. If the truss is assumed to be pin jointed, then the member should ideally be connected by means of a single pin or bolt.
- However, in practice, if the pin or bolt diameter works out to be larger than that possible, more than one bolt will be used. The truss can then be considered pin-jointed only if the bending due to self-weight or other superimposed loads beta joints is negligible.

Connections

- Connection elements consist of components such as cleats, gusset plates, brackets, connecting plates and connectors such as rivets, bolts, pins, and weld.
- The connections provided in steel structures can be classified as 1) riveted 2) bolted and 3) welded connections. 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.

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. 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 or stronger than the base metal, thereby placing no restriction on the joints. Stress concentration effect is also considerably less in a welded connection.

Fundamentals of welding

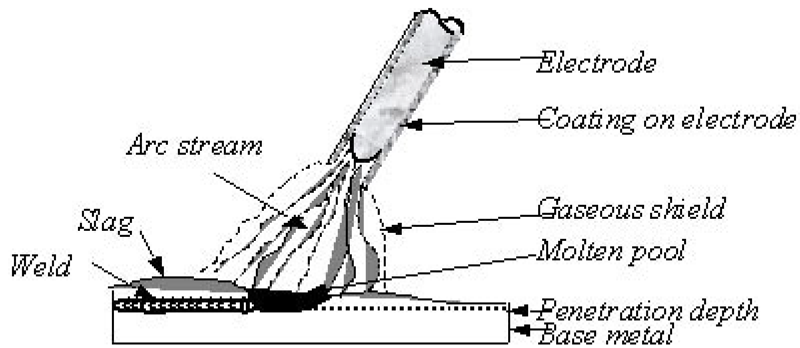
- A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding.
- The inter-diffusion between the materials that are joined is the underlying 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

- 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

Welding process

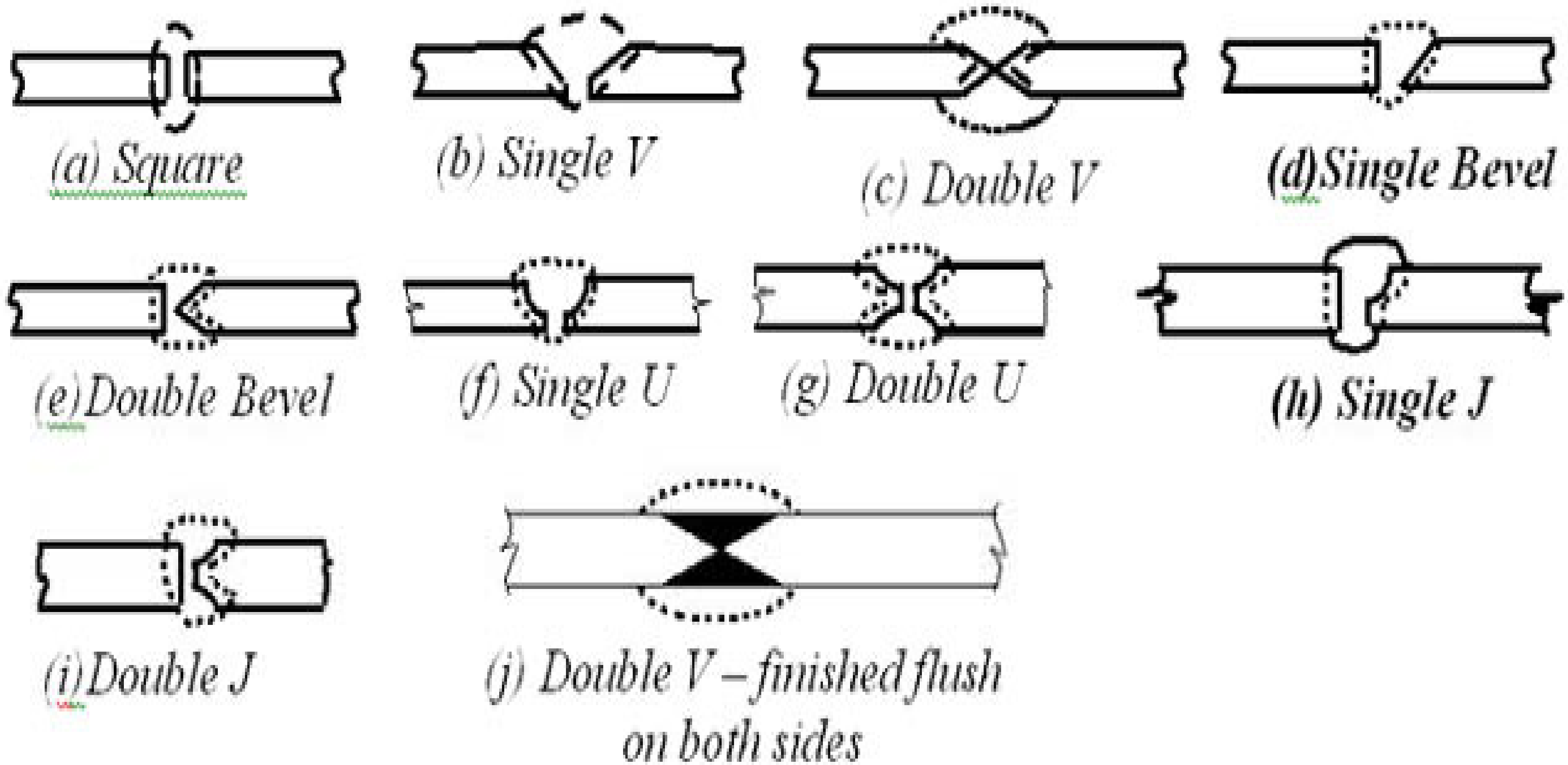
- In general, gas and arc welding are employed; but, almost all structural welding is arc welding. In gas welding a mixture of oxygen and some suitable gas is burned at the tip of a torch held in the welder’s hand or by an automatic machine.
- Acetylene is the gas used in structural welding and the process is calleoxyacetylene welding. The flame produced can be used both for cutting and welding of metals.
- 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.
- The most common welding processes, especially for structural steel, use electric energy as the heat source produced by the electric arc.
- IS:816 in this process, the base metal and the welding rod are heated to the fusion temperature by an electric arc. The arc is a continuous spark formed when a large current at a low voltage is discharged between the electrode and the base metal through a thermally ionised gaseous column, called plasma.

Shielded metal arc welding (SMAW) process



Types of joints and welds

- Lap joint,
- Tee joint,
- Butt joint
- Corner joint.
- 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.
- 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

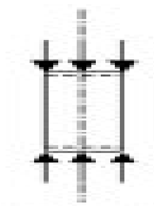

(a) Square
(b) Single V
(c) Double V
(d)Single Bevel
(e)Double Bevel
(f) Single U
(g) Double U
(h) Single J
(i)Double J
(j) Double V – finished flush on both sides

Summary

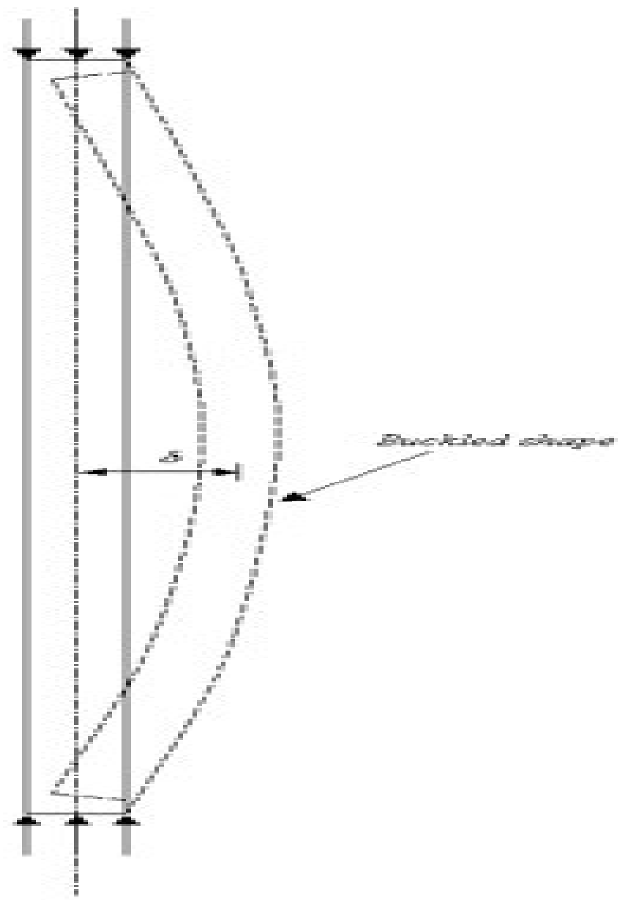
- Different types of bolted connections were described and classified.
- The bearing and friction grip bolts were introduced and their installation procedures described.
- The force transfer mechanisms were explained and the failure modes and corresponding strength calculations were given. This will help in the design of simple bolted connections as in the worked examples.
- Simple analysis methods for bolt groups resisting in-plane and out-of-plane moments were described. Beam and column splices as well as various types of beam-to-column connections were described and their general behaviour as well as points to be kept in mind during their design was explained.

COMPRESSION MEMBERS

- Column, top chords of trusses, diagonals and bracing members are all examples of compression members.
- Columns are usually thought of as straight compression members whose lengths are considerably greater than their cross-sectional dimensions.
- Columns and struts are termed **“long” or “*short” depending on their proneness to buckling. If the strut is “short”, the*** applied forces will cause a compressive strain, which results in the shortening of the strut in the direction of the applied forces. Under incremental loading, this shortening continues until the column yields or **"squashes". However, if the strut is “long”, similar** axial shortening is observed only at the initial stages of incremental loading.
- Thereafter, as the applied forces are increased in magnitude, the strut becomes **“unstable” and** develops a deformation in a direction normal to the loading axis and its axis is no longer straight. (See Fig.1). The strut is said to have “buckled”.



A "short" column fails by compression yield

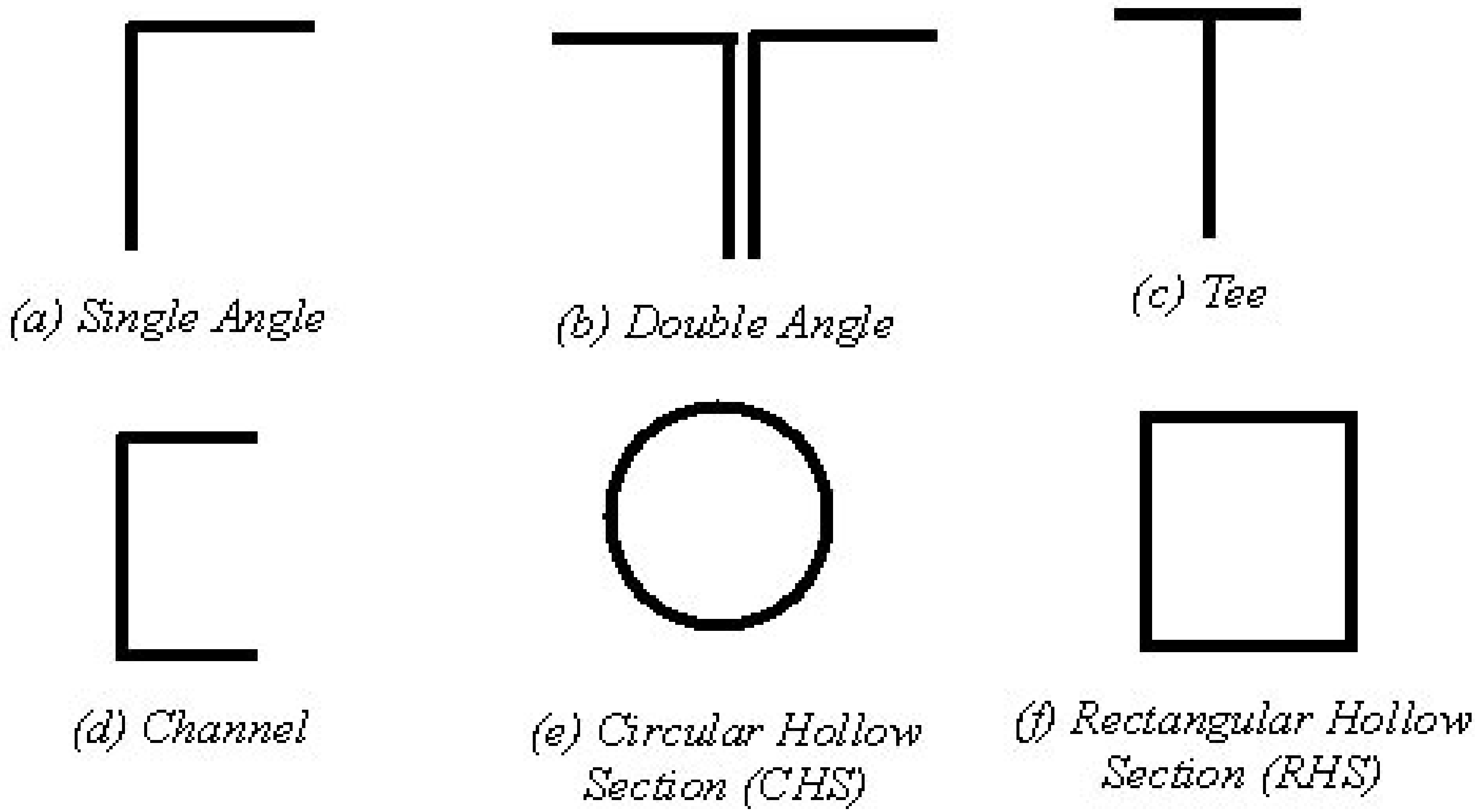


A "long" column fails by predominant buckling

short' vs 'long' columns

- Buckling behaviour is thus characterized by large deformations developed in a direction (or plane) normal to that of the loading that produces it. When the applied loading is increased, the buckling deformation also increases.
- Buckling occurs mainly in members subjected to compressive forces. If the member has high bending stiffness, its buckling resistance is high. Also, when the member length is increased, the buckling resistance is decreased.
- Thus the buckling resistance is high when the member is short or **"stocky" (i.e. the member has a high bending stiffness and is short) conversely, the** buckling resistance is low when the member is long or **"*slender*".**

Cross Section Shapes for Rolled Steel Compression Members



- Structural steel has high yield strength and ultimate strength compared with other construction materials. Hence compression members made of steel tend to be slender compared with reinforced concrete or prestressed concrete compression members.
- Buckling is of particular interest while employing slender steel members.
- Members fabricated from steel plating or sheeting and subjected to compressive stresses also experience local buckling of the plate elements.
- This chapter introduces buckling in the context of axially compressed struts and identifies the factors governing the buckling behaviour. Both global and local buckling is instability phenomena and should be avoided by an adequate margin of safety

- Traditionally, the design of compression members was based on Euler analysis of ideal columns which gives an upper band to the buckling load.
- However, practical columns are far from ideal and buckle at much lower loads. The first significant step in the design procedures for such columns was the use of Perry Robertsons curves.
- Modern codes advocate the use of multiple-column curves for design. Although these design procedures are more accurate in predicting the buckling load of practical columns, Euler's theory helps in the understanding of the behaviour of slender columns and is reviewed in the following sections.

Steps in the design of axially loaded columns

(i) Assume a suitable trial section and classify the section in accordance with the classification in chapter.

(ii) Arrive at the effective length of the column by suitably considering the end conditions.

(iii) Calculate the slenderness ratios (λ values) in both minor and major axes direction and also calculate λo using the formula given below:

$$\lambda_0 = 0.2\pi\sqrt{E/f_y}$$

Calculate fcd values along both major and minor axes from equation given in IS code.

(v) Compute the load that the compression member can resist ($P_d = A_c F_{cd}$)

(vi) Calculate the factored applied load and check whether the column is safe against the given loading. The most economical but safe section can be arrived at by trial and error, i.e. repeating the above process.

Summary

- In the previous sections, the behaviour of practical columns subjected to
- axial compressive loading was discussed and the following conclusions were drawn.
- Very short columns subjected to axial compression fail by yielding. Very long columns fail by buckling in the Euler mode.
- Practical columns generally fail by inelastic buckling and do not conform to the assumptions made in Euler theory. They do not normally remain linearly elastic upto failure unless they are very slender.
- Slenderness ratio (l/r) and material yield stress (fy) are dominant factors affecting the ultimate strengths of axially loaded columns.
- The compressive strengths of practical columns are significantly affected by (i) the initial imperfection (ii) eccentricity of loading (iii) residual stresses and (iv) lack of distinct yield point and strain hardening.

DESIGN OF BEAMS

INTRODUCTION

- Generally, a beam resists transverse loads by bending action.
- In a typical building frame, main beams are employed to span between adjacent columns; secondary beams when used – transmit the floor loading on to the main beams.
- In general, it is necessary to consider only the bending effects in such cases, any torsional loading effects being relatively insignificant. The main forms of response to uni-axial bending of beams are listed in Table 1.

- Under increasing transverse loads, beams of category 1 [Table1] would attain their full plastic moment capacity. This type of behaviour has been covered in an earlier chapter. Two important assumptions have been made therein to achieve this ideal beam behaviour. They are:

- The compression flange of the beam is restrained from moving laterally, and
- ♦ Any form of local buckling is prevented.

- If the laterally unrestrained length of the compression flange of the beam is relatively long as in category 2 of Table 1, then a phenomenon, known as *lateral buckling* or *lateral torsional buckling* of the beam may take place. The beam would fail well before it could attain its full moment capacity.

- This phenomenon has a close similarity to the Euler buckling of columns, triggering collapse before attaining its squash load (full compressive yield load).

- Lateral buckling of beams has to be accounted for at all stages of construction, to eliminate the possibility of premature collapse of the structure or component.

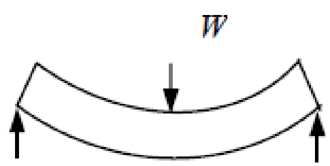
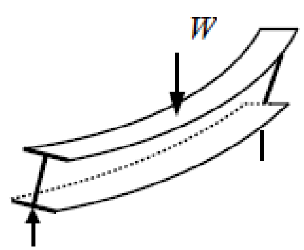
- For example, in the construction of steel-concrete composite buildings, steel beams are designed to attain their full moment capacity based on the assumption that the flooring would provide the necessary lateral restraint to the beams.

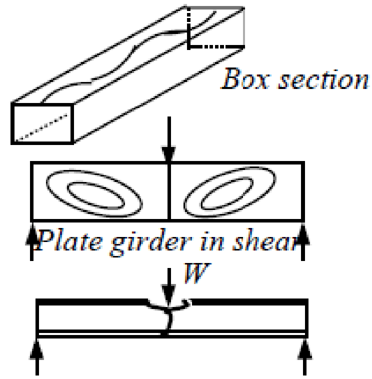
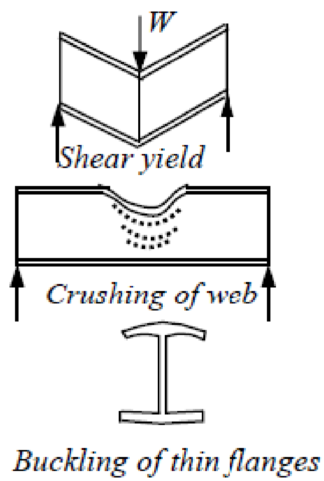
- However, during the erection stage of the structure, beams may not receive as much lateral support from the floors as they get after the concrete hardens. Hence, at this stage, they are prone to lateral buckling, which has to be consciously prevented.

- Beams of category 3 and 4 given in Table 1 fail by local buckling, which should be prevented by adequate design measures, in order to achieve their capacities.

Table 1 Main failure modes of hot-rolled beams

Table 1 Main failure modes of hot-rolled beams

Category	Mode		Comments
1	Excessive bending triggering collapse		This is the basic failure mode provided (1) the beam is prevented from buckling laterally,(2) the component elements are at least compact, so that they do not buckle locally. Such "stocky" beams will collapse by plastic hinge formation.
2	Lateral torsional buckling of long beams which are not suitably braced in the lateral direction.(i.e. "un restrained" beams)		Failure occurs by a combination of lateral deflection and twist. The proportions of the beam, support conditions and the way the load is applied are all factors, which affect failure by lateral torsional buckling.

3	Failure by local buckling of a flange in compression or web due to shear or web under compression due to concentrated loads		Unlikely for hot rolled sections, which are generally stocky. Fabricated box sections may require flange stiffening to prevent premature collapse. Web stiffening may be required for plate girders to prevent shear buckling. Load bearing stiffeners are sometimes needed under point loads to resist web buckling.
4	Local failure by (1) shear yield of web (2) local crushing of web (3) buckling of thin flanges.		Shear yield can only occur in very short spans and suitable web stiffeners will have to be designed. Local crushing is possible when concentrated loads act on unstiffened thin webs. Suitable stiffeners can be designed. This is a problem only when very wide flanges are employed. Welding of additional flange plates will reduce the plate b / t ratio and thus flange buckling failure can be avoided.

SIMILARITY OF COLUMN BUCKLING AND LATERAL BUCKLING OF BEAMS

- It is well known that slender members under compression are prone to instability. When slender structural elements are loaded in their strong planes,
- they have a tendency to fail by buckling in their weaker planes. Both axially loaded columns and transversely loaded beams exhibit closely similar failure characteristics due to buckling.

- Column buckling has been dealt with in detail in an earlier chapter. In this section, lateral buckling of beams is described and its close similarity to column buckling is brought out.

- Consider a simply supported and laterally unsupported (except at ends) beam of “short-span” subjected to incremental transverse load at its mid section as shown in Fig.1 (*a*). The beam will deflect downwards i.e. in the direction of the load [Fig. 1(*b*)].

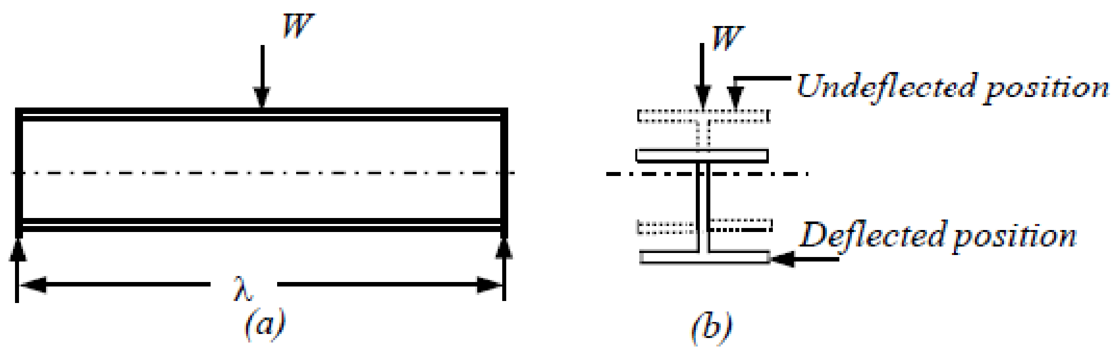


Fig. 1(a) Short span beam, (b) Vertical deflection of the beam.

- The direction of the load and the direction of movement of the beam are the same. This is similar to a short column under axial compression.

- On the other hand, a “long-span” beam [Fig.2 (*a*)], when incrementally loaded will first deflect downwards, and when the load exceeds a particular value, it will tilt sideways due to instability of the compression flange and rotate about the longitudinal axis [Fig. 2(*b*)].

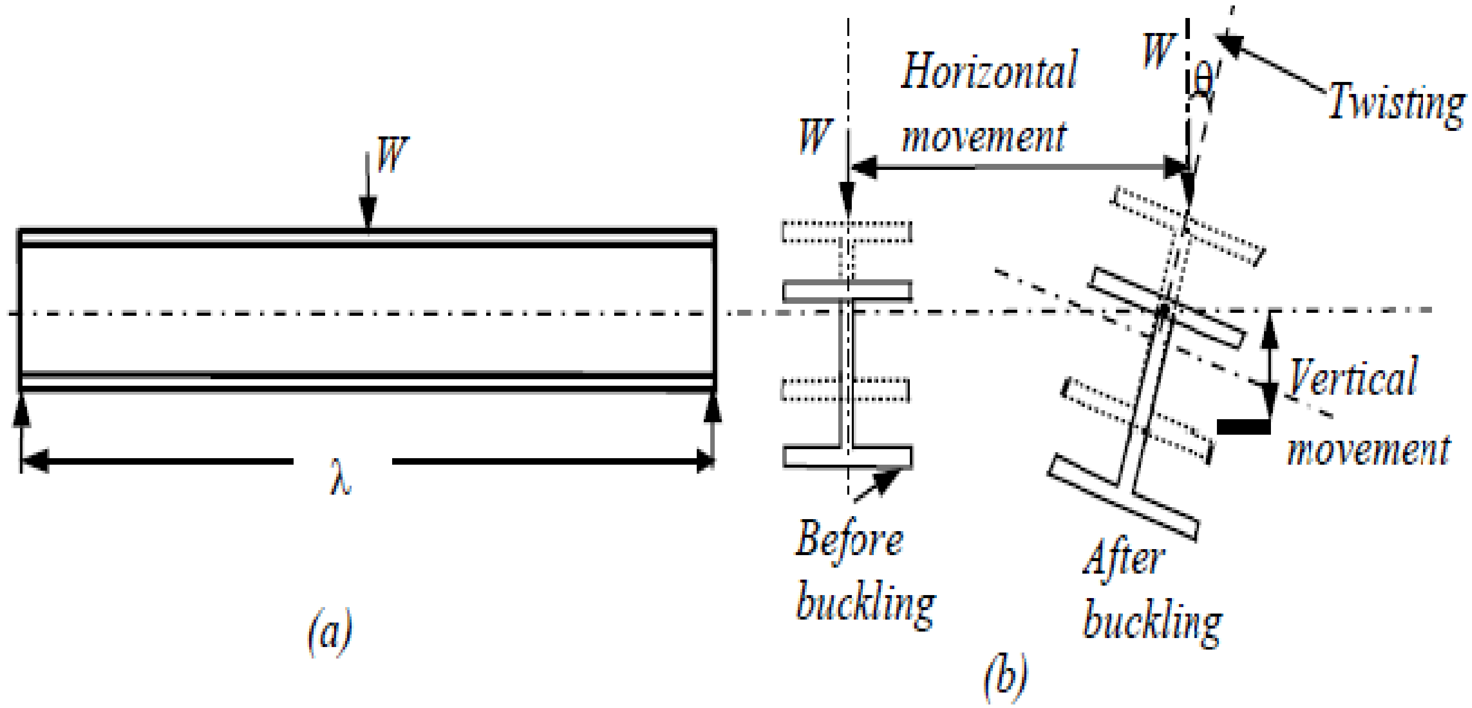


Fig. 2(a) Long span beam, (b) Laterally deflected shape of the beam

- The three positions of the beam cross-section shown in Fig. 2(*b*) illustrate the displacement and rotation that take place as the midsection of the beam undergoes lateral torsional buckling.

- The characteristic feature of lateral buckling is that the entire cross section rotates as a rigid disc without any cross sectional distortion.
- This behaviour is very similar to an axially compressed long column, which after initial shortening in the axial direction, deflects laterally when it buckles.
- The similarity between column buckling and beam buckling is shown in Fig. 3.

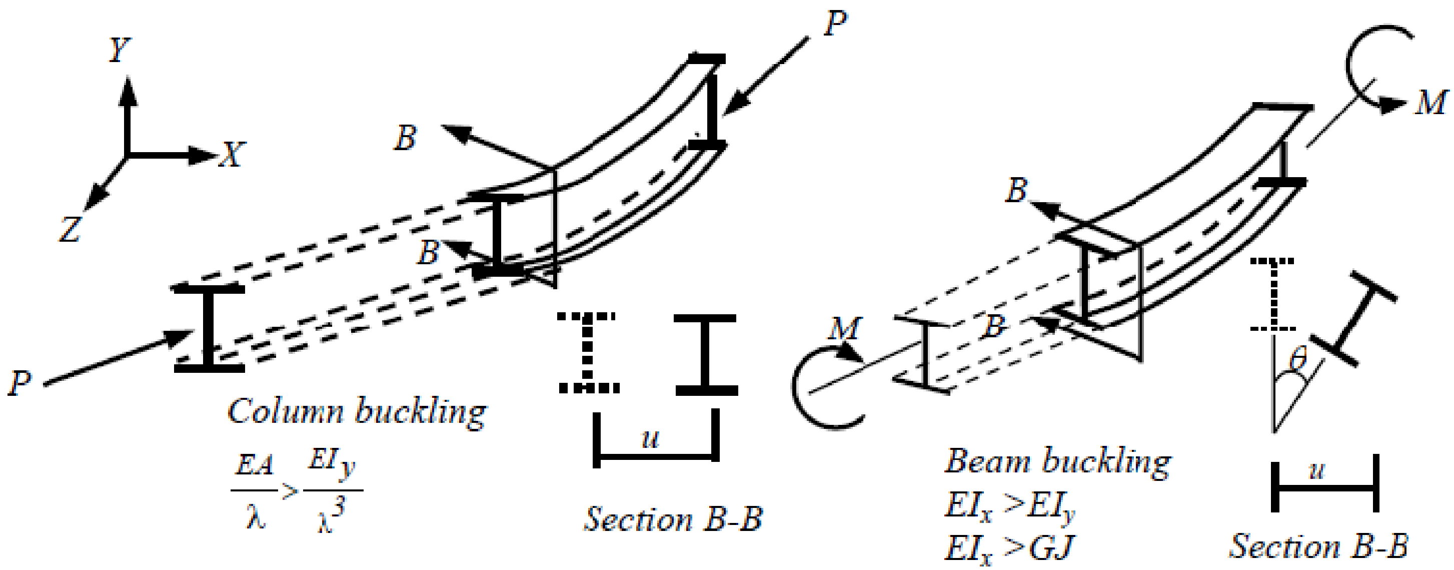


Fig. 3 Similarity of column buckling and beam buckling

- In the case of axially loaded columns, the deflection takes place sideways and the column buckles in a pure flexural mode.
- A beam, under transverse loads, has a part of its cross section in compression and the other in tension.

- **INFLUENCE OF CROSS SECTIONAL SHAPE ON LATERAL TORSIONAL BUCKLING**
- Structural sections are generally made up of either open or closed sections. Examples of open and closed sections are shown in Fig. 4.

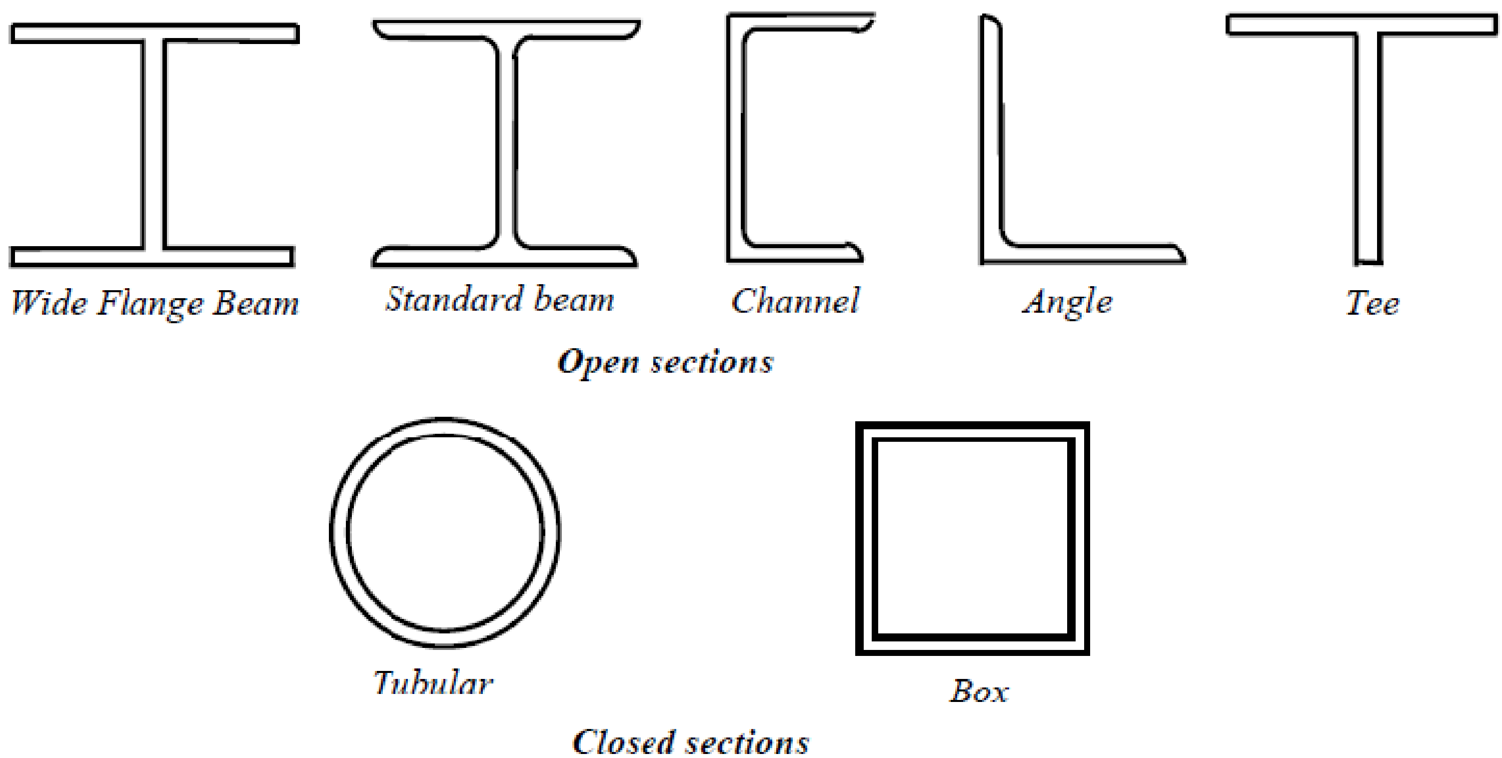


Fig. 4 Open and closed sections

BEAM COLUMNS

- The Indian steel code is now in the process of revision as specification-based design gives way to performance-based design. An expert committee mainly comprising eminent academics from IIT Madras, Anna University Chennai, SERC Madras and INSDAG Kolkata was constituted to revise IS: 800 in LSM version.
- The Limit State Method (referred to as LSM below) is recognized, as one of the most rational methods toward realization of performance-based design, but to date there are no steel-intensive buildings in India that have been designed using LSM.
- We considered that, because building collapse is caused by excessive deformation, the ultimate state should be evaluated from the deformation criteria.
- The proposed design procedure evaluates the ultimate limit state on the basis of the deformation capacity of structural members.
- The magnification factors, used to confirm suitable flexural mechanisms, severely affect the overall probability of failure, and should be determined so that the overall probability of failure does not exceed specific allowable limits.

- In practice, the structural members are generally subjected to various types of combination of stress resultants.
- Depending upon external actions over the members in structural framing system, the combined forces may be broadly categorized as i) Combined Shear and Bending, ii) Combined Axial Tension and Bending and iii) Combined Axial Compression and Bending.
- Normally, the design of an individual member in a frame is done, by separating it from the frame and dealing with it as an isolated substructure.
- The end conditions of the member should then comply with its deformation conditions, in the spatial frame, in a conservative way, e.g. by assuming a nominally pinned end condition, and the internal action effects, at the ends of the members, should be considered by applying equivalent external end moments and end forces.
- Before proceeding for any analysis, classification of these members shall have to be satisfied in accordance with clause no. 3.7 and all related sub-clauses under section 3 of IS: 800 – LSM version.

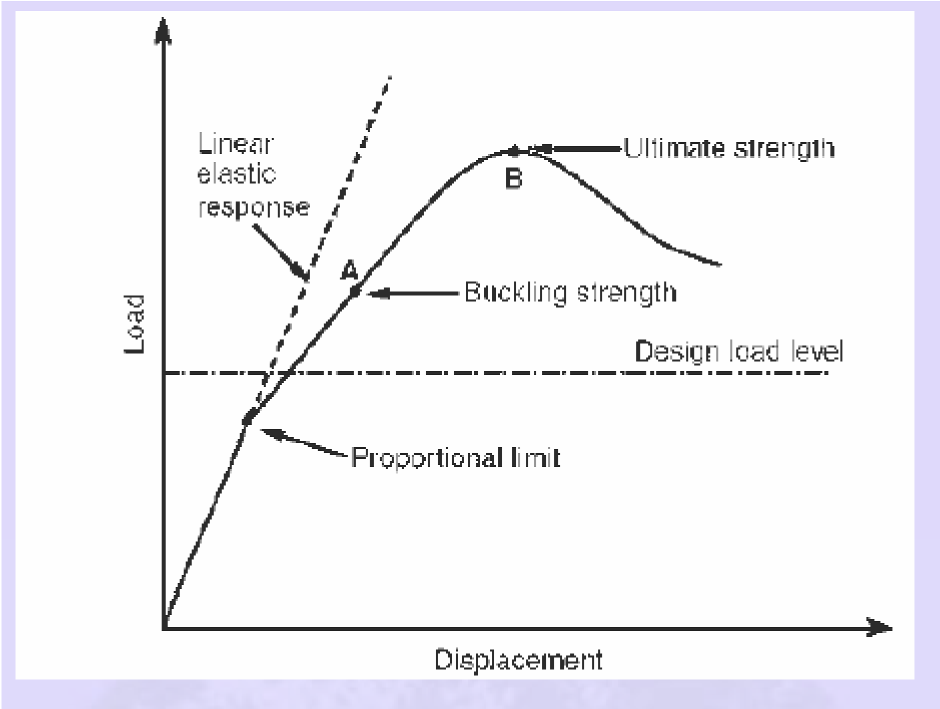
- For all practical purposes, we can equate the third case with the case of Beam columns.
- Beam-columns are defined as members subject to combined bending and compression. In principle, all members in moment resistant framed structures (where joints are considered as rigid) are actually beam-columns, with the particular cases of beams (F = 0) and columns (M = 0) simply being the two extremes.
- Depending upon the exact way in which the applied loading is transferred into the member, the form of support provided and the member's cross-sectional shape, different forms of response will be possible.
- Recently, IS: 800, the Indian Standard Code of Practice for General Construction in Steel is in the process of revision and an entirely new concept of limit state method of design has been adopted in line with other international codes of practice such as BS,EURO, and AISC.
- Additional Sections and features have been included to make the code a state-of-the-art one and for efficient & effective use of structural steel. Attempt has been made in the revised code to throw some light into the provisions for members subjected to forces, which are combined in nature.

Concept of limit state design of beam columns

- Steel structures are important in a variety of land-based applications, including industrial (such as factory sheds, box girder cranes, process plants, power and chemical plants etc.), infrastructural (Lattice girder bridges, box girder bridges, flyovers, institutional buildings, shopping mall etc.) and residential sector.
- The basic strength members in steel structures include support members (such as rolled steel sections, hollow circular tubes, square and rectangular hollow sections, built-up sections, plate girders etc.), plates, stiffened panels/grillages and box girders.
- During their lifetime, the structures constructed using these members are subjected to various types of loading which is for the most part operational, but may in some cases be extreme or even accidental.
- Steel-plated structures are likely to be subjected to various types of loads and deformations arising from service requirements that may range from the routine to the extreme or accidental. The mission of the structural designer is to design a structure that can withstand such demands throughout its expected lifetime.
- The structural design criteria used for the *Serviceability Limit State Design* (hereafter termed as **SLS) design of steel-plated structures are normally based on the** limits of deflections or vibration for normal use. In reality, excessive deformation of a structure may also be indicative of excessive vibration or noise, and so, certain interrelationships may exist among the design criteria being defined and used separately for convenience.

- The structural design criteria to prevent the *Ultimate Limit State Design (hereafter* termed as ULS) are based on plastic collapse or ultimate strength. The simplified ULS design of many types of structures has in the past tended to rely on estimates of the buckling strength of components, usually from their elastic buckling strength adjusted by a simple plasticity correction. This is represented by point A in Figure-1.
- In such a design scheme based on strength at point A, the structural designer does not use detailed information on the post-buckling behavior of component members and their interactions. The true ultimate strength represented by point B in Figure -1 may be higher although one can never be sure of this since the actual ultimate strength is not being directly evaluated

Structural design considerations based on the ultimate limit state



- In the structural design process, **“analysis” usually means the determination of**the stress resultants, which the individual structural members must be capable to resist. **“Design” can mean the development of the structural layout, or arrangement of** members, but it usually means the selection of sizes of members to resist the imposed forces and bending moments.
- Three methods of analysis are available, i.e. elastic analysis, plastic analysis and advanced analysis. Limit state design is a design method in which the performance of a structure is checked against various limiting conditions at appropriate load levels.
- The limiting conditions to be checked in structural steel design are ultimate limit state and serviceability limit state. Limit state theory includes principles from the elastic and plastic theories and incorporates other relevant factors to give as realistic a basis for design as possible

Special features of limit state design method are:

- Serviceability and the ultimate limit state design of steel structural systems and their components.
- Due importance has been provided to all probable and possible design conditions that could cause failure or make the structure unfit for its intended use.
- The basis for design is entirely dependent on actual behaviour of materials in structures and the performance of real structures, established by tests and long-term observations
- The main intention is to adopt probability theory and related statistical methods in the design. It is possible to take into account a number of limit states depending upon the particular instance
- This method is more general in comparison to the working stress method. In this method, different safety factors can be applied to different limit states, which is more rational and practical than applying one common factor (load factor) as in the plastic design method.
- This concept of design is appropriate for the design of structures since any development in the knowledge base for the structural behaviour, loading and materials can be readily implemented.

Summary

- This lecture note constitutes the limit state method of design for members
- subjected to combined stress resultants as per stipulations of the draft IS: 800 –LSM version where the draft code has dealt mainly with i) combined shear and bending ii) combined axial tension and bending and iii) combined axial compression and bending.
- These are explained in detail. The effect of reduction in bending moment capacity has been explained. The effect of lateral torsional buckling has also been explained. The concept of overall strength determination has been explained. The effect of relevant factors including equivalent uniform moment factor has been discussed

COLUMN BASES

- Column base plates are steel placed at the bottom of columns. The function of the base plate is to transmit column loads to the concrete pedestal. the design of column base plate involves two major steps
- (i) Determining the size H x B of the plate and
- (ii) Determining the thickness tp of the plate.

- Generally the size of the plate is fixed based on the limit state of bending on concrete and the thickness of the plate arrived is based on the limit stage of plastic bending of critical section, for the plate.
- Depending on the type of forces (axial force, bending moment or shear force) the plate will be subjected to , the design procedure which may differ slightly.
- In all case, a layer of grout should be provided between the base plate and its support for the purpose of leveling and anchor bolt should be provided to stabilize the column during erection or to prevent uplift for cases involving large bending moment

Design Steps

Step1. Sketch the column at the junction of the base plate

Step2. Choose cleat angles such that ta > tf. Preferably an unequal angle with long leg connected to the column.

Step3. Assume φ of anchor bolts 20 - 38mm φ neck area is 80% of cross sectional area

Step4. Find e = M / P and find w +ve or -ve.

Step5. Find 'a' the distance of the centre of windward anchor bolts from the compression edge.

Step6. Solve equation and get x, assuming B and find using given equations.