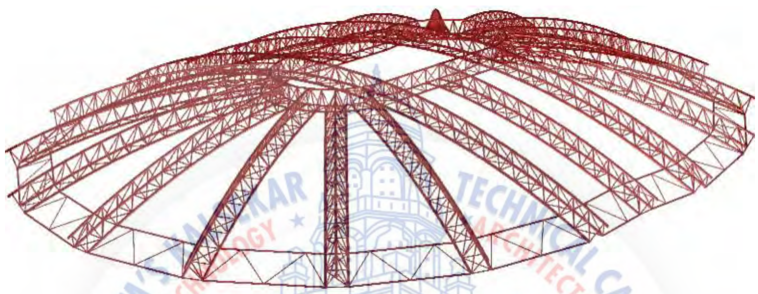
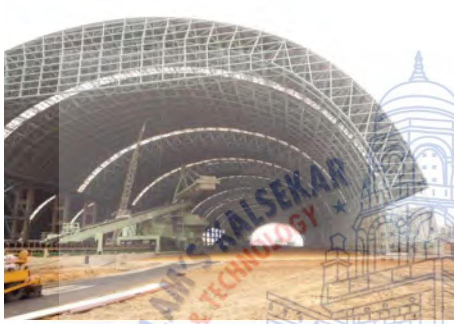
DDSS

Design And Drawing of Steel Structures

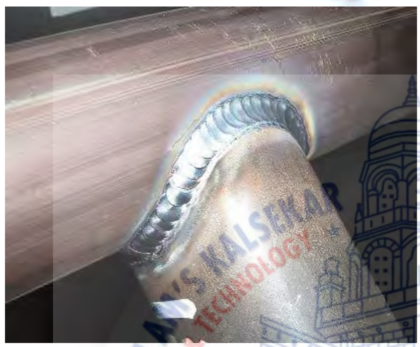
(Year 2017-18)

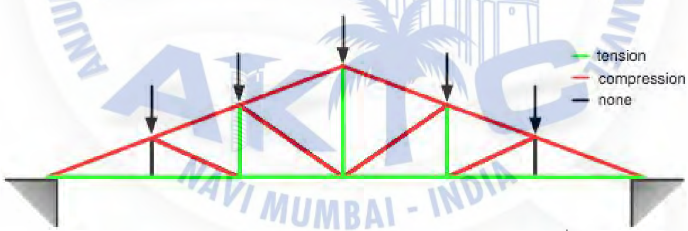
Hwelikar S.C.







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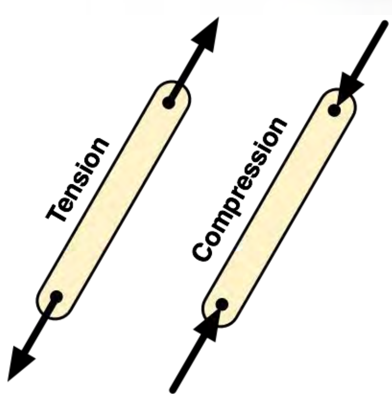
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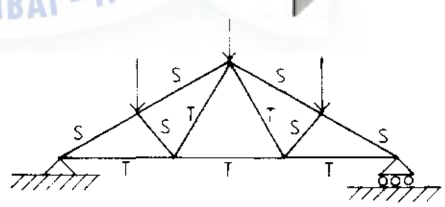
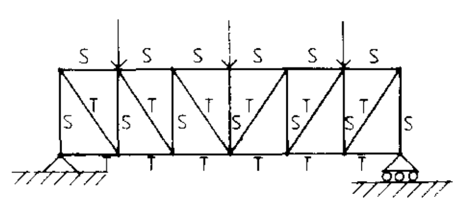
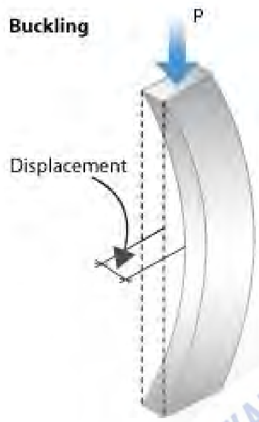
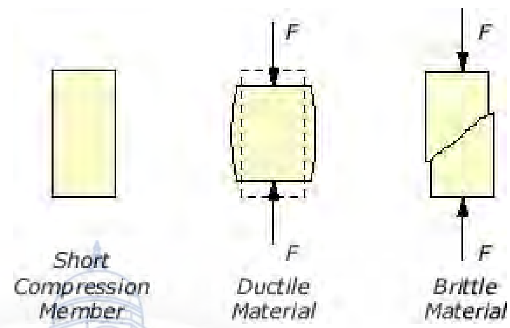







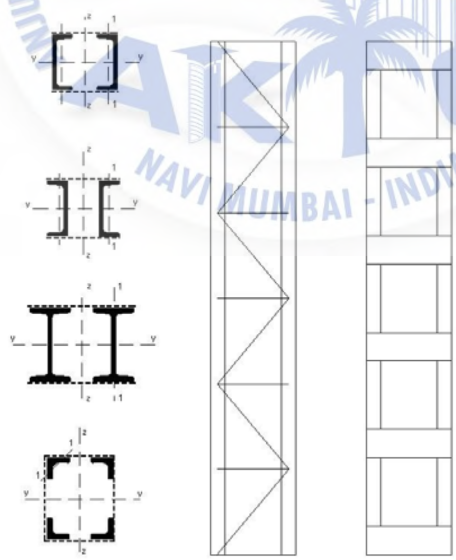
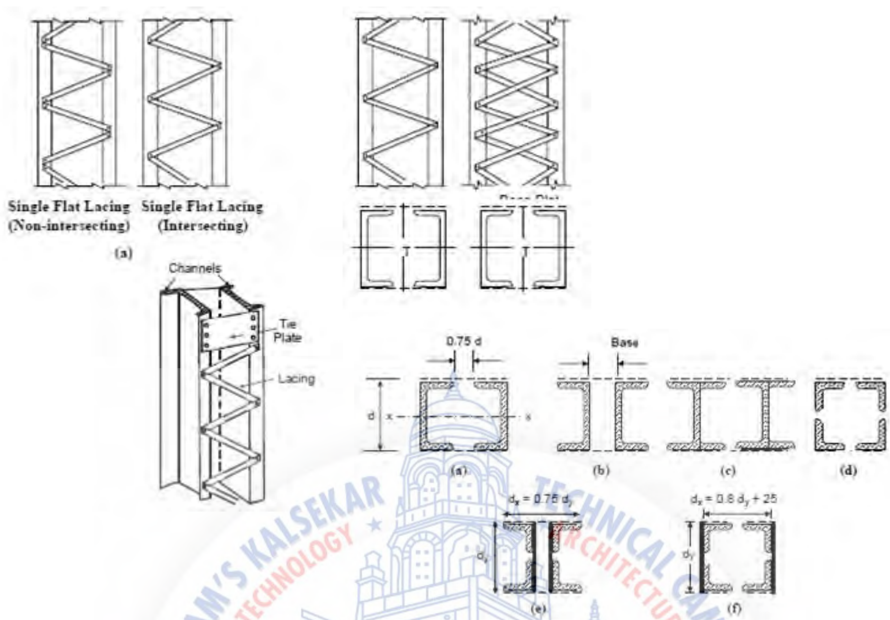


Figure 1 Built-up columns


Single Flat Lacing
(Non-intersecting)
Single Flat Lacing
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(a)
Channels
Tie Plate
Lacing
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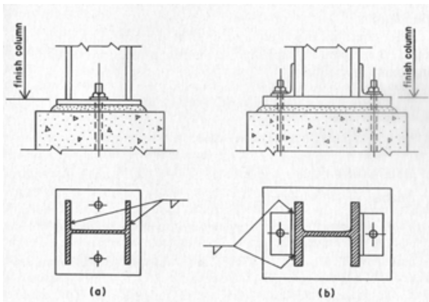
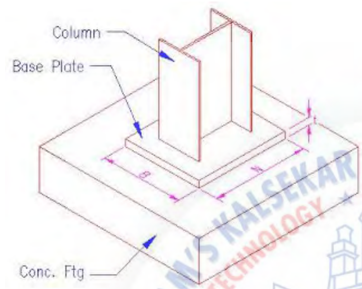
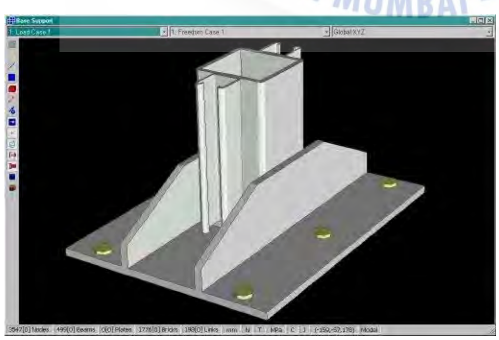
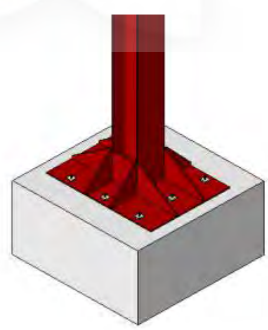
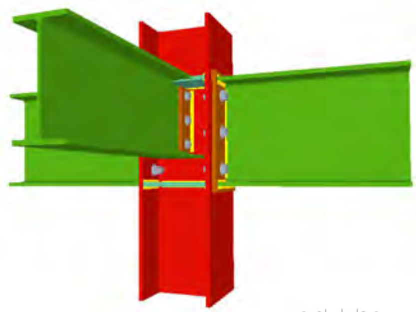


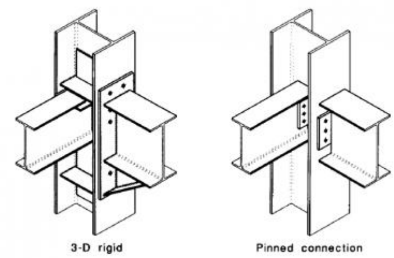
Figure 11.5 Typical column base details.

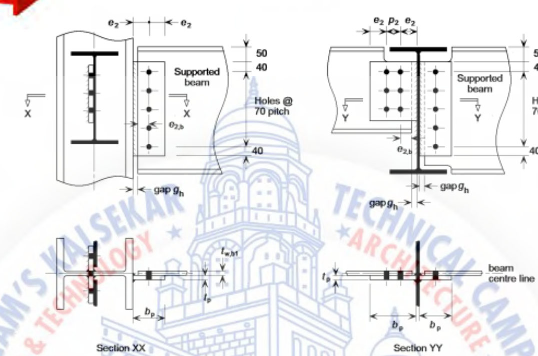












Introduction

Design of a building consists of two parts viz. (i) functional design and (ii) structural design. The first part consists in planning the building to serve its requirements taking into account ventilation, lighting, aesthetic view etc. The structural design consists in proportioning various elements of the building such that loads acting on it are transferred safely to the ground and at the same time unnecessarily excess material is not used.

For transferring the loads to the ground various materials, like asbestos sheets, tiles, bricks, cement concrete, reinforced concrete, steel, aluminium are used. However, main body of the present-day structures consists of R.C.C or steel. In tall structures composite construction of steel and concrete is also commonly used.

Steel has high strength per unit mass. Hence it is used in constructing large column-free structures. The following are the common steel structures in use:

1. Roof trusses for factories, cinema halls, auditoriums etc.
2. Trussed bents, crane girders, columns etc., in industrial structures.
3. Roof trusses and columns to cover platforms in railway stations and bus stands.
4. Single layer or double layer domes for auditoriums, exhibition halls, indoor stadiums etc.
5. Plate girder and truss bridges for railways and roads.
6. Transmission towers for microwave and electric power.
7. Water tanks.
8. Chimneys etc.

The advantages of steel over other materials for construction are:

1. It has high strength per unit mass. Hence even for large structures, the size of steel structural element is small, saving space in construction and improving aesthetic view.
2. It has assured quality and high durability.
3. Speed of construction is another important advantage of steel structure. Since standard sections of steel are available which can be prefabricated in the workshop/site, they may be kept ready by the time the site is ready and the structure erected as soon as the site is ready. Hence there is lot of saving in construction time.
4. Steel structures can be strengthened at any later time, if necessary. It needs just welding additional sections.
5. By using bolted connections, steel structures can be easily dismantled and transported to other sites quickly.
6. If joints are taken care, it is the best water and gas resistant structure. Hence can be used for making water tanks also.
7. Material is reusable.

The disadvantages of steel structures are:

1. It is susceptible to corrosion.
2. Maintenance cost is high, since it needs painting to prevent corrosion.
3. Steel members are costly.

The properties of steel required for engineering design may be classified as

(i) Physical Properties
(ii) Mechanical Properties.

(i) *Physical Properties*: Irrespective of its grade physical properties of steel may be taken as given below (clause 2.2.4 of IS 800-2007):

(a) Unit mass of steel, $\rho = 7850$ kg/m^3.
(b) Modulus of elasticity, $E = 2.0 \times 10^5$ N/mm^2.
(c) Poisson's ratio, $\mu = 0.3$.
(d) Modulus of rigidity, $G = 0.769 \times 10^5$ N/mm^2.
(e) Coefficient of thermal expansion, $\alpha_t = 12 \times 10^{-6}$/°C.

(ii) *Mechanical Properties:* The following are the important mechanical properties in the design:

(a) Yield stress f_y.
(b) The tensile or ultimate stress f_u.

INTRODUCTION

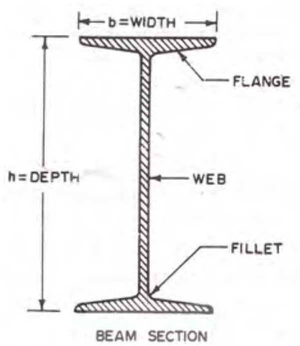
- The steel sections manufactured in rolling mills and used as structural members are known as **rolled structural steel sections.**
- The steel sections are named according to their cross sectional shapes.
- The shapes of sections selected depend on the types of members **which are fabricated and to some extent on the process of erection.**
- Many steel sections are readily available in the market and have frequent demand. Such steel sections are known as **regular steel sections.**
- Some steel sections are rarely used. Such sections are produced on special requisition and are **known as special sections.**
- '**ISI Handbook for Structural Engineers'** gives nominal dimensions, weight and geometrical properties of various rolled structural steel sections.

TYPES OF ROLLED STRUCTURAL STEEL SECTIONS

Rolled Steel I-sections (Beam sections).

- Rolled Steel Channel Sections.
- Rolled Steel Tee Sections.
- Rolled Steel Angles Sections.
- Rolled Steel Bars.
- Rolled Steel Tubes.
- Rolled Steel Flats.
- Rolled Steel Sheets and Strips.
- Rolled Steel Plates.

TYPES OF ROLLED STRUCTURAL STEEL SECTIONS



- The rolled steel beams are classified into following four series as per BIS : (IS : 808-1989)
- Indian Standard Joist/junior Beams ISJB
- Indian Standard Light Beams ISLB
- Indian Standard Medium Weight Beams ISMB
- Indian Standard Wide Flange Beams ISWB

- The rolled steel columns/heavy weight beams are classified into the following two series as per BIS (IS : 808-1989)
- Indian Standard Column Sections ISSC
- Indian Standard Heavy Weight Beams ISHB

- The beam section consists of web and two flanges. The junction between the flange and the web is known as fillet. These hot rolled steel beam sections have sloping flanges. The outer and inner faces are inclined to each other and they intersect at an angle varying from 1½ to 8˚ depending on the section and rolling mill practice. The angle of intersection of ISMB section is 8˚. Abbreviated reference symbols (JB, LB, MB, WB, SC and HB) have been used in designating the Indian Standard Sections as per BIS (IS 808-1989)

- The rolled steel beams are designated by the series to which beam sections belong (abbreviated reference symbols), followed by depth in mm of the section and weight in kN per metre length of the beam,
- e.g., MB 225 @ 0.312 kN/m. H beam sections of equal depths have different weights per metre length and also different properties e.g., WB 600 @ 1.340 kN/m, WB 600 @ 1.450 kN/m, HB 350 @0.674 kN/m, HB 350 @0.724 kN/m.

- I-sections are used as beams and columns. It is best suited to resist bending moment and shearing force. In an I-section about 80 % of the bending moment is resisted by the flanges and the rest of the bending moment is resisted by the web. Similarly about 95% of the shear force is resisted by the web and the rest of the shear force is resisted by the flanges. Sometimes I-sections with cover plates are used to resist a large bending moment. Two I-sections in combination may be used as a column.

- The rolled steel Channel sections are classified into four categories as per ISI, namely,
- Indian Standard Joist/Junior Channels ISJC
- Indian Standard Light Channels ISLC
- Indian Standard Medium Weight Channels ISMC
- Indian Standard Medium Weight Parallel Flange Channels ISMCP

- As per IS : 808-1989, following channel sections have also been additionally adopted as Indian Standard Channel Secions
- Indian Standard Light Channels with parallel flanges ISLC(P)
- Medium weight channels MC
- Medium weight channels with parallel flanges MCP
- Indian Standard Gate Channels ISPG

- The rolled steel tee sections are classified into the following five series as per ISI:
- Indian Standard Normal Tee Bars ISNT
- Indian Standard Wide flange Tee Bars ISHT
- Indian Standard Long Legged Tee Bars ISST
- Indian Standard Light Tee Bars ISLT
- Indian Standard Junior Tee Bars ISJT

- A per IS: 808-1984, following T-sections have also been additionally adopted as Indian Standard T-sections.

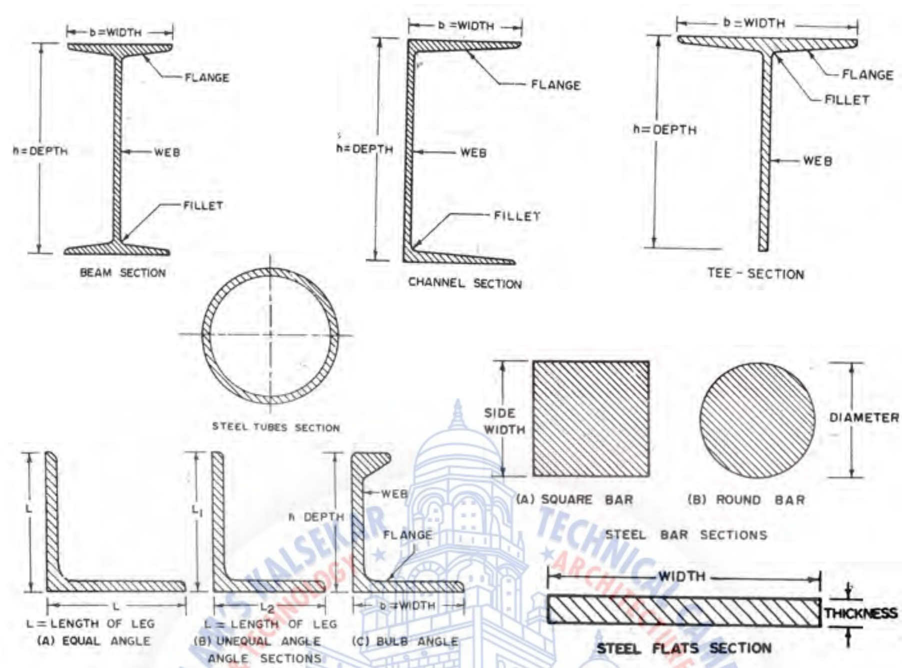
- Indian Standard deep legged Tee bars ISDT
- Indian Standard Slit medium weight Tee bars ISMT
- Indian Standard Slit Tee bars from I-sections ISHT

- The rolled steel angle sections are classified in to the following three series.

- Indian Standard Equal Angles ISA
- Indian Standard Unequal Angles ISA
- Indian Standard Bulb Angles ISBA

- The rolled steel bars are classified in to the following two series:

- Indian Standard Round Bars ISRO
- Indian Standard Square Bars ISSQ



Rolled steel plates of the following thicknesses are available:

5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 71, 80 mm.

They are rolled in the widths

160, 180, 200, 220, 250, 280, 320, 355, 400, 450, 500, 560, 630, 710, 800, 900, 1000, 1100, 1250, 1400, 1600, 1800, 2000, 2200, 2500 mm.

Rolled steel strip is designated as ISST followed by width and thickness. These sections are available in the following width and thickness:

Width: 100, 110, 125, 140, 160, 180, 200, 220, 250, 280, 320, 355, 400, 450, 500, 560, 630, 710, 800, 900, 1000 mm.

Thickness: 0.8, 0.9, 1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.2, 3.5, 4.0, 4.5 mm.

Flats differ from strips in the sense that the thickness of flats is 5 mm onward and their width is limited. Flats of the following width and thickness are listed in IS Handbook.

Width: 12, 16, 20, 25, 32, 40, 50, 63, 80, 100, 125, 160, 200, 250 mm.

Thickness: 5, 5.5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18, 20, 22, 25 mm.

They are designated by width followed by letters ISF and thickness e.g:

80 ISF 10 means, 80 mm wide Indian Standard Flat of thickness 10 mm.

CLASSIFICATION OF STRUCTURES

- The structures may be classified as statically determinate structures and statically indeterminate structures. When the equation of statics (ΣH=0, ΣV=0 and ΣM=0) are enough to determine all the forces acting on the structure and in the structures are known as statically determinant structures.

- When the equation of equilibrium are not sufficient to determine all the forces acting on the structures and in the structure, then the structures are known as statically indeterminate structures. The equations of consistent deformations are added to the equations of equilibrium in order to analyze the statically indeterminate structures.

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CLASSIFICATION OF STRUCTURES

- The structures are also classified as shell structures and framed structures. The shell roof covering of large buildings, air planes, rail road cars, ship wells, tanks etc are the examples of shell structures. The plates or sheets serve functional and structural purposes.

- The plates act as a load carrying elements. The plates are stiffened by frames which may or may not carry the principal loads. The framed structures are built by assemblies of elongated members. The truss frames, truss girders, rigid frames etc are the examples of framed structures. The main members are used for the transmission of loads.

- The structures may be further classified depending on the materials used as plastic structures, aluminium structures, timber structures, R.C.C structures and steel structures.

ADVANTAGES OF STEEL STRUCTURES

Steel has a high strength and so steel components have smaller sections for the same strength compared to corresponding components of other material.The existing steel structures and structural component may be strengthened by connecting additional sections or plates.

- Steel members are gas and watertight, because of high density of steel.
- Steel structures can be fabricated at site easily.
- Steel structures have great durability and serve for many years.
- Steel members can be readily disassembled or replaced.
- The existing steel structures and structural component may be strengthened by connecting additional sections or plates.

- **DISADVANTAGES OF STEEL STRUCTURES**
- Steel structures are liable to corrosion and need painting frequently.
- Steel structures have a low fire resistance and are liable to lose their strength and get deformed at high temperature.

STRUCTURAL STEEL

- The structural steel is the steel used for the manufacture of rolled structural steel sections, fastenings and other elements for use in structural steel works. Steel is an alloy of iron, carbon and other elements in varying percentages.
- The strength, hardness and brittleness of steel increases and ductility of steel decreases with the increase of percentage of carbon.
- Depending on the chemical composition, the different type of steel are classified as mild steel, medium carbon steel, high carbon steel, low alloy steel and high alloy steel.
- The mild steel, medium carbon steel and low alloy steel are generally used for steel structures. The copper bearing quality of steel contains small percentage of copper contents. The corrosive resistance of such steel is increased.

STRUCTURAL STEEL

- Mild steel is used for the manufacture of rolled structural steel sections, rivets and bolts. The following operations can be done easily on mild steel **1.Cutting, 2. Punching, 3.Drilling, 4. Machining, 5. Welding and 6. Forging when heated.** All structural steels used in general construction, coming within the purview of IS:800-84 shall, before fabrication, comply with one of the following Indian Standard specifications
- IS : 226-1975 structural steel (standard quality)
- IS : 1977-1975 structural steel (ordinary quality)
- IS : 2062-1984 weldable structural steel
- IS : 961-1975 structural steel (high tensile)
- IS : 8500-1977 weldable structural steel (medium and high strength qualities)
- 1.6.1 IS : 226-1975 structural steel (standard quality).
- The mild steel is designated as St 44-S for use in structural work. This steel is also available in copper bearing quality in which case it designated as St 44-SC. The copper content is between 0.20 and 0.35 per cent. The physical properties of structural steel are given below:
- Unit weight of steel 78.430 to 79.000 kN/m3
- Young's modulus of elasticity, E=2.04 to 2.18 x 105 N/mm2
- Modulus of rigidity, G=0.84 to 0.98 x 105 N/mm2
- Coefficient of thermal expansion (or contraction) α=12 x 10-6/˚C or 6.7 x 10-6/˚F.

Loads on structures

- The structures and structural members are designed to meet the **functional and structural aspects.** Both aspects are interrelated.
- The functional aspect takes in to consideration the purpose for which the building or the structure is designed.
- It includes the determination of location and arrangement of **operating utilities, occupancy, fire safety and compliance with hygienic, sanitation, ventilation, special equipment, machinery or other features, incident to the proper functioning of the structures.**

Loads on structures

- In the structural aspect, it is ensured that the building or the structure is structurally safe, strong, durable and economical.
- The minimum requirements pertaining to the structural safety of buildings are being covered in codes dealing with loads by way of laying down minimum **design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear.**
- Unnecessarily, heavy loads without proper assessment should not be assumed. The structures are designed between **two limits, namely, the structural safety and economy.** The structures should be strong, stable and stiff.

- Estimation of the loads for which a structure should be designed is one of the most difficult problems in structural design. The designer must be able to study the loads which are likely to be acting on the structure throughout its life time and the loads to which the structure may be subjected during a short period.
- It is also necessary to consider the combinations of loads for which the structure has to be designed.

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- It is also necessary to consider the combinations of loads for which the structure has to be designed.

The load combinations for design purpose shall be the one that produces maximum forces and effects and consequently maximum stresses from the following combinations

- Dead load + Imposed (live) load
- Dead load + Imposed (live) load + wind or earthquake loads and
- Dead load + wind or earthquake loads

TYPES OF LOADS

- The loads to which a structure, will be subjected to consist of the following

1. Dead loads,
2. Live loads or imposed loads,
3. Wind load,
4. Snow load
5. Seismic load
6. Temperature effects

- In addition o the above loads, following forces and effects are also considered.

1. Foundation movements
2. Elastic axial shortening
3. Soil and fluid pressures
4. Vibrations
5. Fatigue
6. Impact
7. Erection loads
8. Stress concentration effects

Stresses on structures

- When a structural member is loaded, deformation of the member takes place and resistance is set up against deformation.
- This resistance to deformation is known as stress.
- The stress is defined as force per unit cross sectional area.
- The nature of stress developed in the structural member depends upon nature of loading on the member.

TYPES OF LOADS

- The following are the various types of stresses:

1. Axial stress (direct stress) : i. Tensile stress ii. Compressive stress
2. Bearing stress
3. Bending stress
4. Shear stress

- A member may be subjected to combined direct and bending stress. Such stress is known as combined stress.
- The tensile stresses are taken as positive and compressive stress as negative.
- This sign convention for stresses is convenient as a structural member elongates on application of tensile load and shortens on application of compressive load.

TENSILE STRESS

- When a structural member is subjected to direct axial tensile load, the stress is known as tensile stress (σat). The tensile stress is calculated on net cross-sectional area of the member:

$$\sigma_{at} = (Pt/An)$$

- Where Pt is the direct axial tensile load and An is the net cross-sectional area of the member.

COMPRESSIVE STRESS

- When a structural member is subjected to direct axial compressive load, the stress is known as compressive stress (σac). The compressive stress is calculated on gross cross-sectional area of the member

$$\sigma_{ac} = (Pc/Ag)$$

- Where Pc is the direct axial compressive load and Ag is the gross cross-sectional area of the member

BEARING STRESS

- When a load is exerted or transferred by the application of load through one surface for the another surface in contact, the stress is known as 'bearing stress'(σb). the bearing stress is calculated on net projected area of contact

$$\sigma b = (P/A)$$

- Where P is load placed on the bearing suface and A is the net projected area of contact.

INFO VIDEO

- HOT Rolled Steel Section

- Cold Rolled Steel Sections

The following special considerations are required in the steel design:

1. Size and Shape
2. Buckling
3. Minimum Thickness
4. Connection Designs.

Size and Shape: Steel is manufactured in steel mills and is available in certain shapes and sizes. Hence the member of a steel structure should be designed to consist of any of the available sections or a combination of them. For example, a beam section may be a standard I-section or it may consist of built up sections as shown in Fig. 1.5.

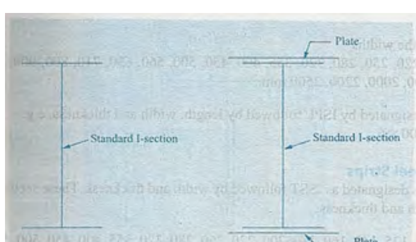


Figure 1.5 Standard section and built up section.

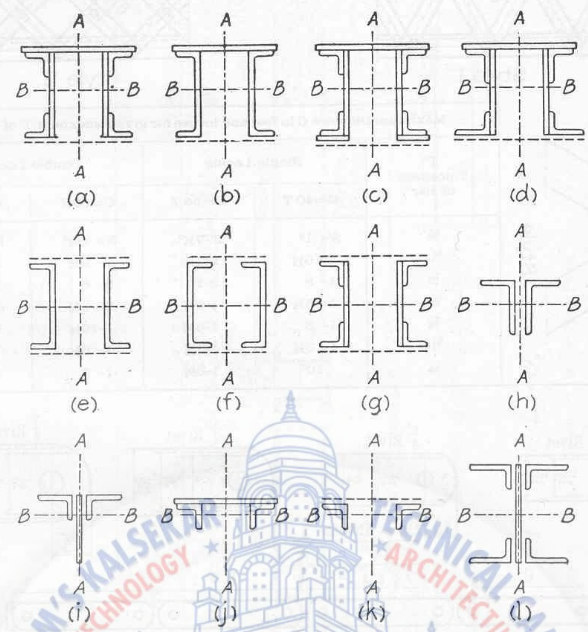


FIG. 7. RIVETED SECTIONS FOR COMPRESSION MEMBERS.

2. *Buckling Consideration:* The permissible load per unit area in steel is much higher as compared to permissible values in concrete. Therefore, for the same load, the cross sectional area of a steel member is smaller. As the members in a steel structure are more slender, the compression members in steel structure are liable to buckling. In case of beams, there are chances of lateral buckling which creates special problems. As a steel member consists of a number of thin plates, the stability of each part is to be considered. To account for buckling phenomenon, codes specify that part of sections be taken as ineffective.

3. *Minimum Thickness:* Corrosion needs special consideration in steel design. If very thin sections are used, a small amount of corrosion may result into a large percentage reduction in effective area. Hence design practice specify minimum thicknesses to be used in structural members. For the members directly exposed to weather the following minimum thickness is to be used:

(a) If fully accessible for cleaning and painting – 6 mm.
(b) If not accessible for cleaning and painting – 8 mm.
(c) The above limitations do not apply for rolled steel sections, tubes and cold formed light gauge sections. However IS 800-2007, has dropped the specification for minimum thickness.

4. *Need for Design of Connections:* A steel design is not complete if the following connections are not designed:

(a) Connections between various standard sections selected for a member
(b) Connections between various members (like beam, column, foundation etc.) of the structure.

The following three types of connections are commonly used:

(a) Riveted Connections
(b) Bolted Connections
(c) Welded Connections.

(a) Dead Loads (DL)
(b) Imposed Loads (IL)
(c) Wind Loads (WL)
(d) Earthquake Loads (EL)
(e) Erection Loads (ER)
(f) Accidental Loads (AL)
(g) Secondary Effects.

(b) *Imposed Loads:* IS 800-2007 groups the following

(i) Live load
(ii) Crane load
(iii) Snow load
(iv) Dust load
(v) Hydrostatic and earth pressure
(vi) Impact load
(vii) Horizontal loads on parapets and balustrades.

In a particular building, live load may change from room to room. For example, in a hotel or a hostel building the loads specified are,

	UDL	Concentrated Load
(a) Living rooms and bedrooms	2 kN/m^2	1.8 kN
(b) Kitchen	3 kN/m^2	4.5 kN
(c) Dining rooms	4 kN/m^2	2.7 kN
(d) Office rooms	2.5 kN/m^2	2.7 kN
(e) Store rooms	5 kN/m^2	4.5 kN
(f) Rooms for indoor games	3 kN/m^2	1.8 kN
(g) Bathrooms and toilets	2 kN/m^2	–
(h) Corridors, passages, staircases etc., and	3 kN/m^2	4.5 kN
(i) Balconies	4 kN/m^2	1.5 kN concentrated at outer edge

1.8 LOAD COMBINATIONS

A judicious combination of the loads is necessary to ensure the required safety and economy in the design keeping in view the probability of

(a) their acting together
(b) their disposition in relation to other loads and severity of stresses or deformation caused by the combination of various loads.

The recommended load combinations by IS 875 are as given below.

1	DL	7	DL + IL + EL
2	DL + IL	8	DL + IL + TL
3	DL + WL	9	DL + WL + TL
4	DL + EL	10	DL + EL + TL
5	DL + TL	11	DL + IL + WL + TL
6	DL + IL + WL	12	DL + IL + EL + TL

Where

DL = Dead Load IL = Imposed Load
WL = Wind Load EL = Earthquake Load
and TL = Temperature Load.

Note: When snow load is present on roofs, replace imposed load by snow load for the purpose of above load combinations.

1.9 STRUCTURAL ANALYSIS

Structural analysis is necessary to find the internal forces developed in the members of the structures. The required internal forces for design are axial forces and moments. IS code permits the following methods of analysis:

(a) Elastic Analysis
(b) Plastic Analysis
(c) Advanced Analysis
(d) Dynamic Analysis.

(i) Working Stress Method (WSM)
(ii) Ultimate Load Design (ULD) and
(iii) Limit State Design (LSD).

(i) WORKING STRESS METHOD: This is the oldest systematic analytical design method. Though IS 80 2007 insists for the limit state design, permits use of this method wherever LSD cannot be convenient adopted.

In this method stress strain relation is considered linear till the yield stress. To take care of uncertainti in the design, permissible stress is kept as a fraction of yield stress, the ratio of yield stress to worki stress itself known as factor of safety. The members are sized so as to keep the stresses within the pe missible value. Thus

$$\text{permissible stress} = \frac{\text{yield stress}}{\text{factor of safety}}$$

The following load combinations are considered and increase of permissible stress by 33% is permitt when DL, LL and WL are considered:

Stress due to DL + LL ≤ permissible stress
Stress due to DL + WL ≤ permissible stress
Stress due to DL + LL + WL ≤ 1.33 permissible stress.

The limitations of WSM

The limitations of working stress method are:

1. It gives the impression that factor of safety times the working load is the failure load, which is not true. Actually it is much more, because a material can resist the load after yield appears at a fibre. In the indeterminate structures just formation of a plastic hinge is not the failure criteria, since it can resist load till some more hinges are formed resulting into collapse mechanism. Thus the redistribution of moments gives rise to the additional load carrying capacity.
2. It gives uneconomical sections.

Figure 3.1 Riveting.

Riveting has the following disadvantages:

(a) It is associated with high level of noise pollution.
(b) It needs heating the rivet to red hot.
(c) Inspection of connection is a skilled work.
(d) Removing poorly installed rivets is costly.
(e) Labour cost is high.

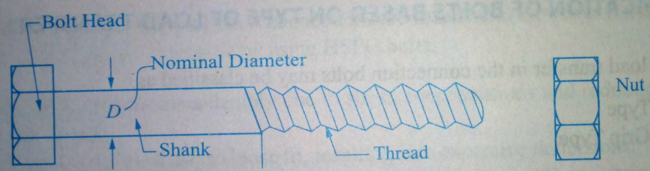


Figure 3.2 Bolt and nut.

The following are the **advantages** of bolted connections over riveted or welded connection

1. Making joints is noiseless.
2. Do not need skilled labour.
3. Needs less labour.
4. Connections can be made quickly.
5. Structure can be put to use immediately.
6. Accommodates minor discrepancies in dimensions.
7. Alterations, if any, can be done easily.
8. Working area required in the field is less.

The **disadvantages** of unfinished (black) bolt connections are listed here. However it may be noted t most of these disadvantages are overcome by using HSFG bolts.

1. Tensile strength is reduced considerably due to stress concentrations and reduction of area a the root of the threads.
2. Rigidity of joints is reduced due to loose fit, resulting into excessive deflections.
3. Due to vibrations nuts are likely to loosen, endangering the safety of the structures.

The following terms used in the bolted connections are defined below:

1. *Pitch of the bolts (p):* It is the centre to centre spacing of the bolts in a row, measured along the direction of load. It is shown as 'p' in Fig. 3.3.
2. *Gauge Distance (g):* It is the distance between the two consecutive bolts of adjacent rows and is measured at right angles to the direction of load. (Ref. Fig. 3.3)

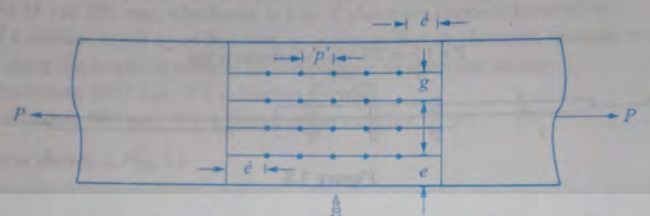


Figure 3.3 Pitch, gauge distance and edge distance.

3. *Edge Distance (e):* It is the distance of centre of bolt hole from the adjacent edge of plate (Ref. Fig. 3.3).
4. *End Distance (e'):* It is the distance of the nearest bolt hole from the end of the plate (Ref. Fig. 3.3).
5. *Staggered Distance:* It is the centre to centre distance of staggered bolts measured obliquely on the member as shown in Fig. 3.4.

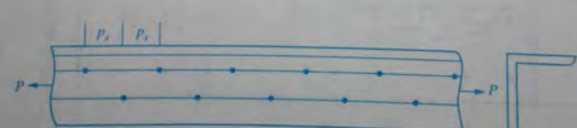


Figure 3.4 Bolt distance in staggered bolts.

3.6 IS 800-2007 SPECIFICATIONS FOR SPACING AND EDGE DISTANCES OF BOLT HOLES

1. Pitch 'p' shall not be less than $2.5d$, where 'd' is the nominal diameter of bolt.
2. Pitch 'p' shall not be more than
   (a) $16t$ or 200 mm, whichever is less, in case of tension members [Fig. 3.5],

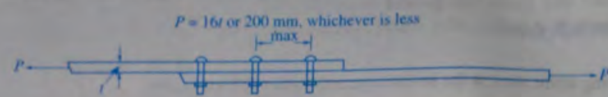


Figure 3.5

   (b) $12t$ or 200 mm, whichever is less, in case of compression members where t is the thickness of thinnest member (Fig. 3.6).

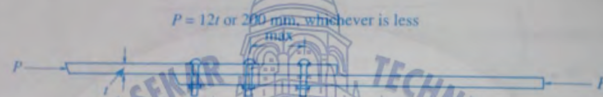


Figure 3.6

   (c) In case of staggered pitch, pitch may be increased by 50 percent of values specified above provided gauge distance is less than 75 mm.

4. The gauge length 'g' should not be more than $100 + 4t$ or 200 mm whichever is less.
5. Minimum edge distance shall not be
   (a) Less than 1.7 × hole diameter in case of sheared or hand flame cut edges
   (b) Less than 1.5 × hole diameter in case of rolled, machine flame cut, sawn and planed edges.
6. Maximum edge distance (e) should not exceed
   (a) $12t\epsilon$, where $\epsilon = \sqrt{\frac{250}{f_y}}$ and t is the thickness of thinner outer plate
   (b) $40 + 4t$, where t is the thickness of thinner connected plate, if exposed to corrosive influences
7. Apart from the required bolt from the consideration of design forces, additional bolts called tacking fasteners should be provided as specified below.
   (a) If value of gauge length exceeds after providing design fasteners at maximum edge distances tacking rivets should be provided
      (i) At 32 t or 300 mm, whichever is less, if plates are not exposed to weather
      (ii) At 16 t or 200 mm, whichever is less, if plates are exposed to weather.
8. In case of a member made up of two flats, or angles or tees or channels, tacking rivets are to be provided along the length to connect its components as specified below:
   (a) Not exceeding 1000 mm, if it is tension member
   (b) Not exceeding 600 mm, if it is compression member

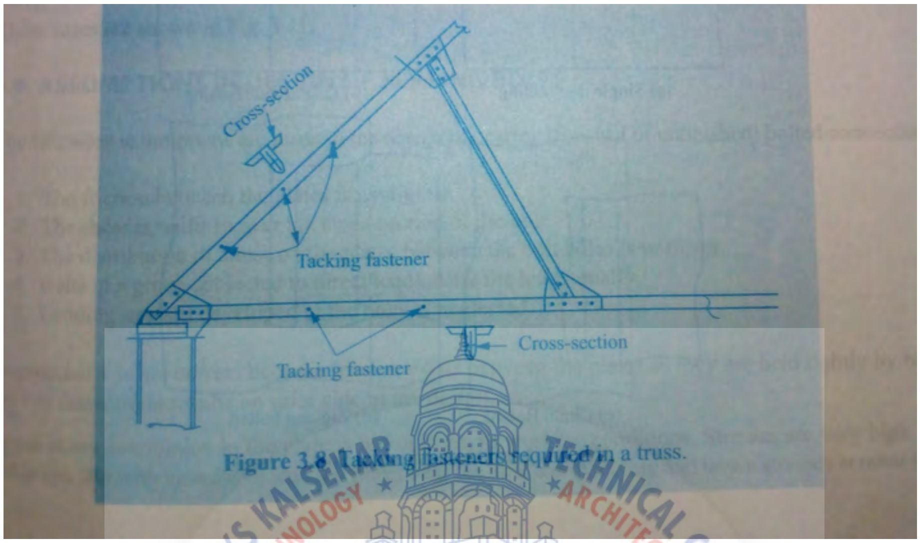
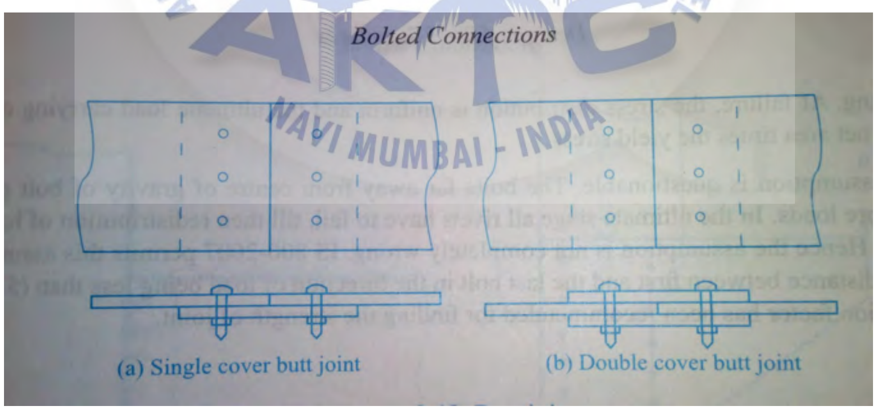


Figure 3.8 Tacking fasteners required in a truss.



3.8 TYPES OF ACTIONS ON FASTENERS

Depending upon the types of connections and loads, bolts are subjected to the following types of actions:

(a) Only one plane subjected to shear (single shear)
(b) Two planes subjected to shear (double shear)
(c) Pure tension
(d) Pure moment
(e) Shear and moments in the plane of connection
(f) Shear and tension.

These cases are shown in Fig. 3.11.

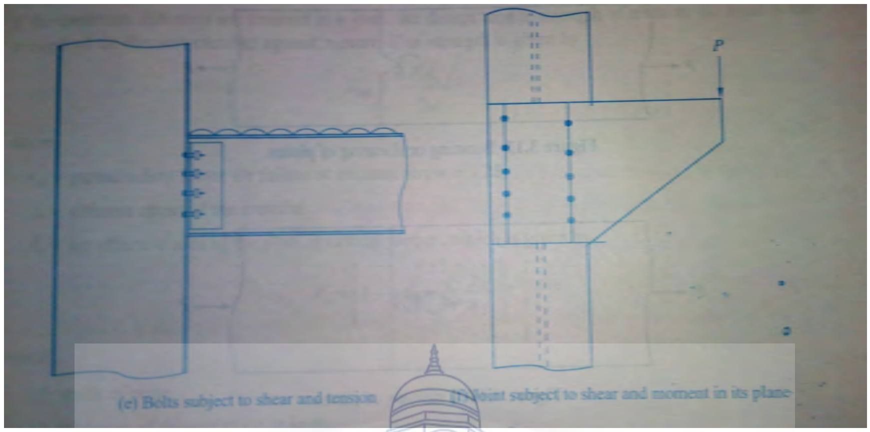
3.9 ASSUMPTIONS IN DESIGN OF BEARING BOLTS

The following assumptions are made in the design of bearing (finished or unfinished) bolted connections:

1. The friction between the plates is negligible
2. The shear is uniform over the cross-section of the bolt
3. The distribution of stress on the plates between the bolt holes is uniform
4. Bolts in a group subjected to direct loads share the load equally
5. Bending stresses developed in the bolts is neglected.

(a) Shear plane on thread

(b) Two planes subject to shear



(e) Bolts subject to shear and tension (f) Joint subject to shear and moment in its plane

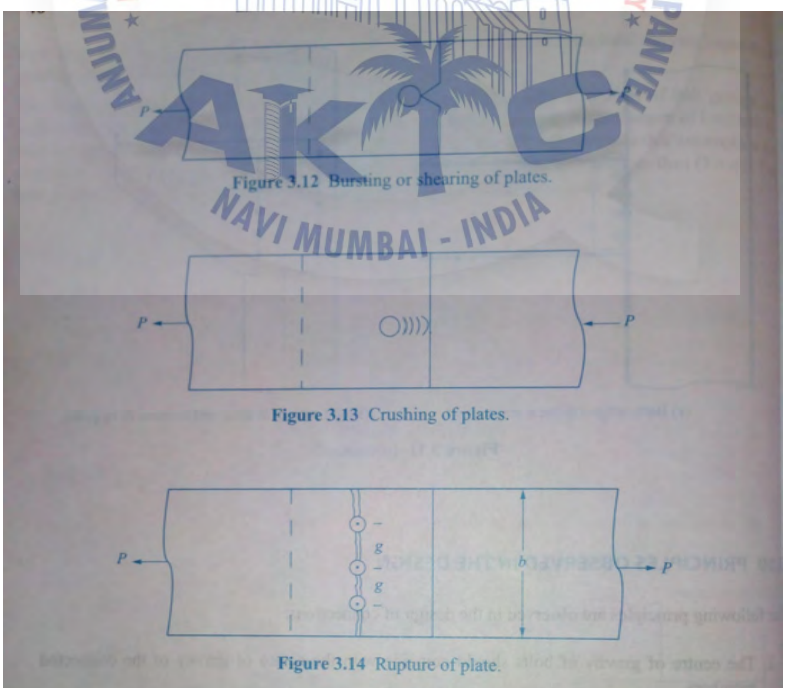


Figure 3.12 Bursting or shearing of plates.

Figure 3.13 Crushing of plates.

Figure 3.14 Rupture of plate.