SYLLABUS

UNIT I INTRODUCTION AND ALLOWABLE STRESS DESIGN

Structural steel types – Mechanical Properties of structural steel- Indian structural steel products-Steps involved in the Deign Process -Steel Structural systems and their Elements- -Type of Loads on Structures and Load combinations- Code of practices, Loading standards and Specifications - Concept of Allowable Stress Method, and Limit State Design Methods for Steel Structures-Relative advantages and Limitations-Strengths and Serviceability Limit states. Allowable stresses as per IS 800 section 11 -Concepts of Allowable stress design for bending and Shear –Check for Elastic Deflection-Calculation of moment carrying capacity –Design of Laterally supported Solid Hot Rolled section beams-Allowable stress deign of Angle Tension and Compression Members and estimation of axial load carrying capacity

UNIT II CONNECTIONS IN STEEL STRUCTURES

Type of Fasteners- Bolts Pins and welds- Types of simple bolted and welded connections Relative advantages and Limitations-Modes of failure-the concept of Shear lag-efficiency of joints- Axially loaded bolted connections for Plates and Angle Members using bearing type bolts –Prying forces and Hanger connection– Design of Slip critical connections with High strength Friction Grip bolts.- Design of joints for combined shear and Tension- Eccentrically Loaded Bolted Bracket Connections-Welds-symbols and specifications- Effective area of welds-Fillet and but Welded connections-Axially Loaded connections for Plate and angle truss members and Eccentrically Loaded bracket connections.

UNIT III TENSION MEMBERS

Tension Members - Types of Tension members and sections –Behaviour of Tension Members-modes of failure-Slenderness ratio- Net area – Net effective sections for Plates ,Angles and Tee in tension –Concepts of Shear Lag- Design of plate and angle tension members-design of built up tension Members-Connections in tension members – Use of lug angles – Design of tension splice

UNIT IV COMPRESSION MEMBERS

Types of compression members and sections–Behaviour and types of failures-Short and slender columns- Current code provisions for compression members- Effective Length, Slenderness ratio –Column formula and column curves- Design of single section and compound Angles-Axially Loaded solid section Columns- Design of Built up Laced and Battened type columns – Design of column bases – Plate and Gusseted bases for Axially loaded colums- Splices for colums.

UNIT V DESIGN OF FLEXURAL MEMBERS

Types of steel Beam sections- Behaviour of Beams in flexure- Codal Provisions – Classification of cross sections- Flexural Strength and Lateral stability of Beams – Shear Strength-Web Buckling, Crippling and defection of Beams- Design of laterally supported Beams- Design of solid rolled section Beams- Design of Plated beams with cover plates - Design Strength of Laterally unsupported Beams – Design of laterally unsupported rolled section Beams- Purlin in Roof Trusses-Design of Channel and I section Purlins.

TEXTBOOKS:

1. Subramanian.N, "Design of Steel Structures", Oxford University Press, New Delhi, 2013.
2. Gambhir. M.L., "Fundamentals of Structural Steel Design", McGraw Hill Education India Pvt. Ltd., 2013
3. Duggal. S.K, "Limit State Design of Steel Structures", Tata McGraw Hill Publishing Company, 2005

ONLINE RESOURCES:

- www.nptel.ac.in

CE8601 - DESIGN OF STEEL STRUCTURAL ELEMENTS		
COURSE OUTCOMES		
After successful completion of the course, the students should be able to		
CO NO	Course Outcomes	Highest Cognitive Level
C310.1	Recognize IS codes of practice for the design of steel structural elements.	k2
C310.2	Solve the bolt and welded connections problems	K3
C310.3	Compute tension members using rolled steel sections	k3
C310.4	Summarize compression members using rolled steel sections	K2
C310.5	Compute and design the flexural member as laterally restrained and unrestrained beams	K3

UNIT I INTRODUCTION AND ALLOWABLE STRESS DESIGN

Structural steel types – Mechanical Properties of structural steel- Indian structural steel products-Steps involved in the Deign Process -Steel Structural systems and their Elements- -Type of Loads on Structures and Load combinations- Code of practices, Loading standards and Specifications - Concept of Allowable Stress Method, and Limit State Design Methods for Steel Structures-Relative advantages and Limitations-Strengths and Serviceability Limit states. Allowable stresses as per IS 800 section 11 -Concepts of Allowable stress design for bending and Shear –Check for Elastic Deflection-Calculation of moment carrying capacity –Design of Laterally supported Solid Hot Rolled section beams-Allowable stress deign of Angle Tension and Compression Members and estimation of axial load carrying capacity

Introduction

- 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 strong 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

- 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 etc. or a combination of these.
- The elements are connected together by means of rivets, bolts or welds.
- Depending on the fixity of these joints, the connections are classified as rigid, semi rigid and flexible.

Structural steel types &properties

- **Structural steel** is a category of steel used for making construction materials in a variety of shapes. Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section.
- Structural steel shapes, sizes, chemical composition, mechanical properties such as strengths, storage practices, etc., are regulated by standards in most industrialized countries.
- Most structural steel shapes, such as **I**-beams, have high second moments of area, which means they are very stiff in respect to their cross-sectional area and thus can support a high load without excessive sagging.

Following properties of structural steel are considered before using them for a construction. These properties are useful for determining the quality of steel. High quality steel is used so that dependable and long-lasting construction is possible. The most important components include the following:

Density

Density of a material is defined as mass per unit volume. Structural steel has density of 7.75 to 8.1 g/cm^3.

Elastic Modulus

Elastic modulus or modulus of elasticity is the measurement of tendency of an object to be deformed when force or stress is applied to it. Typical values for structural steel range from 190-210 gigapascals.

Poisson's Ratio

It is the ratio between contraction and elongation of the material. Lower the value, lesser the object will shrink in thickness when stretched. Acceptable values for structural steel are 0.27 to 0.3.

Tensile Strength

Tensile strength of an object is the determination of limit up to which an object can be stretched without breaking. Fracture point is the point at which an object breaks after application of stress. Structural steel has high tensile strength so is preferred over other materials for construction.

Yield Strength

Yield strength or yield point is the stress at which an object deforms permanently. It cannot return to its original shape when stress is removed. Structural steel made of carbon has yield strengths of 187 to 758 megapascals. Structural steel made of alloys has values from 366 to 1793 megapascals.

Melting Point

There is no defined value for melting point due to the wide variations in types of structural steel. Melting point is the temperature at which object starts to melt when heated.

Specific Heat

Specific heat or heat capacity is the amount of heat which needs to be applied to the object to raise its temperature by a given amount. A higher value of specific heat denotes greater insulation ability of the object. Values are measured in Joules per Kilogram Kelvin. Structural steel made of carbon has values from 450 to 2081 and that made from alloys has values ranging from 452 to 1499.

Hardness

Hardness is the resistance of an object to shape change when force is applied. There are 3 types of hardness measurements. Scratch, indentation and rebound. Structural steel made by using alloys has hardness value between 149-627 Kg. Structural steels made of carbon has value of 86 to 388 Kg.

ADVANTAGES OF STEEL

- It has high strength per unit mass
- The size of steel elements are lesser resulting in space savings an aesthetic view
- It has assured quality and high durability
- Speed of Construction
- It can be strengthened any later time.
- Easy dismantling of steel structures is possible (Mainly by using bolted connection)
- The material is reusable
- If the joints are taken care of, it has good resistance against water and gas.

DISADVANTAGES OF STEEL

- It is susceptible to corrosion
- Maintenance cost is significant (frequent painting is read to prevent corrosion)
- Steel members are costly (Initial cost)



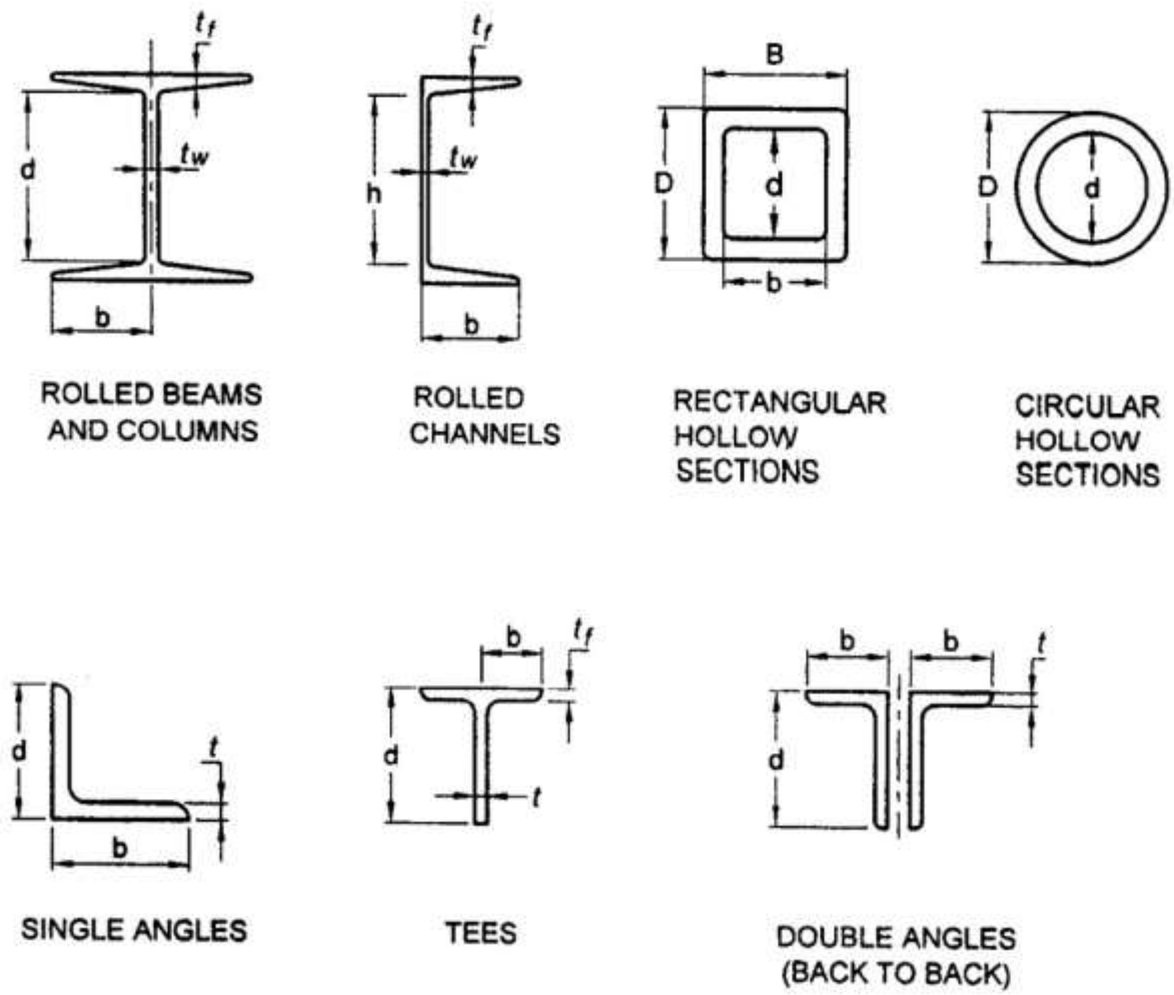


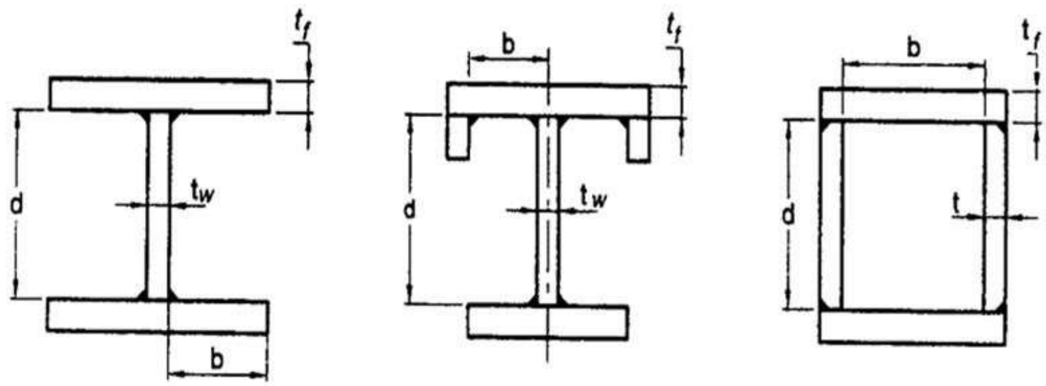


Examples of Steel structures in Practice

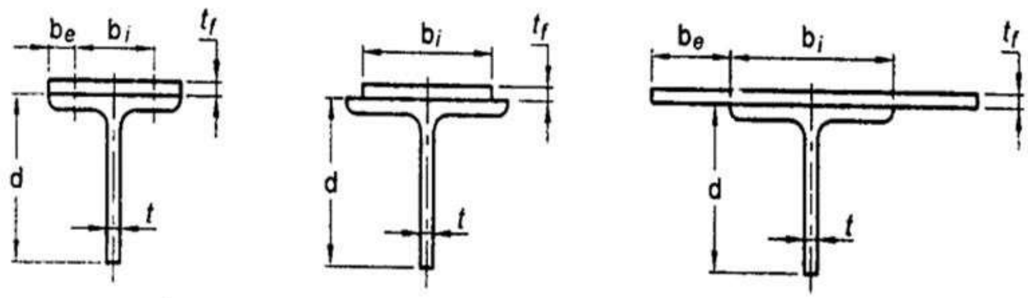
Structural steel sections has been classified by Indian standard based on its ultimate strength

1. Rolled steel section
2. Built up section





BUILT-UP SECTIONS



COMPOUND ELEMENTS

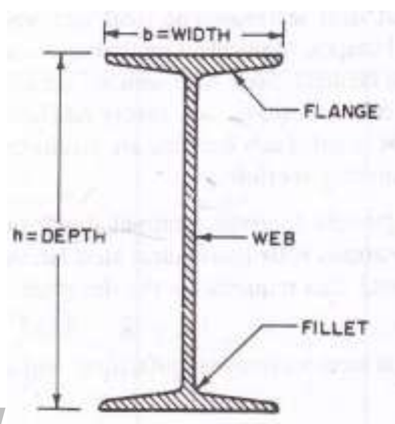
b_i — Internal Element Width

b_e — External Element Width

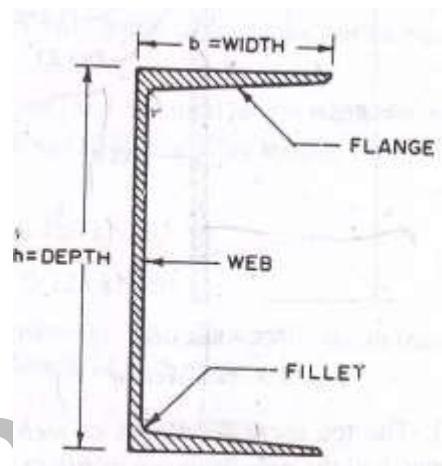
RECENT DEVELOPMENTS IN SECTIONS

The rolled steel beam sections with parallel faces of flanges are recently developed. These beam sections are called as parallel flange sections. These sections have increased moment of inertia, section modulus and radius of gyration about the weak axis. Such sections used as beams and columns have more stability. Theses sections possess ease of connections to other sections as no packing is needed as in beams of slopping flanges. The parallel flange beam sections are not yet rolled in our country.

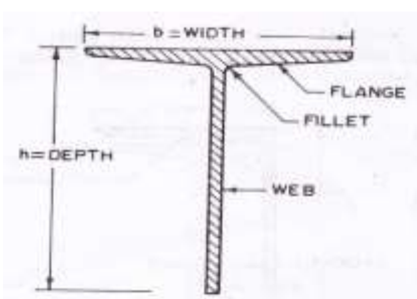
New welded sections using plates and other steel sections are developed because of welding. The development of beams with tapered flanges and tapered depths is also due to welding. The open web sections and the castellated beams were also developed with the rapid use of welding.



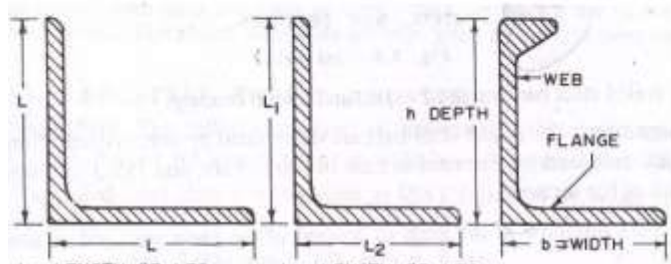
BEAM SECTION



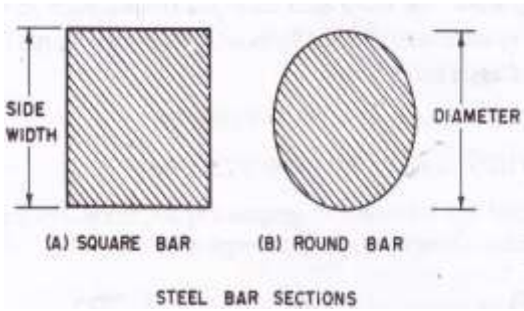
CHANNEL SECTION

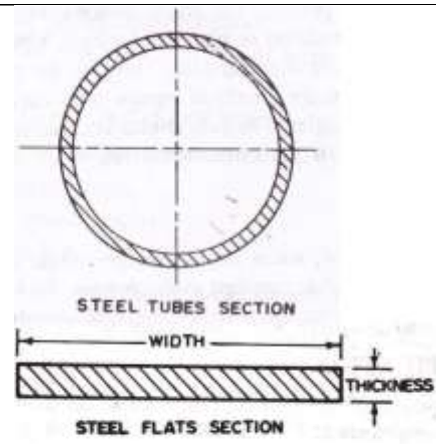


TEE - SECTION



(A) EQUAL ANGLE (B) UNEQUAL ANGLE (C) BULB ANGLE
ANGLE SECTIONS





MECHANICAL PROPERTIES OF STRUCTURAL STEEL

The properties that need to be considered by designers when specifying steel construction. 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. They are

- Strength
- Toughness
- Ductility
- Weldability
- Durability.

The mechanical properties of structural steel is w.r.to the yield stress & ultimate stress of the steel sections conforming to IS 2062.

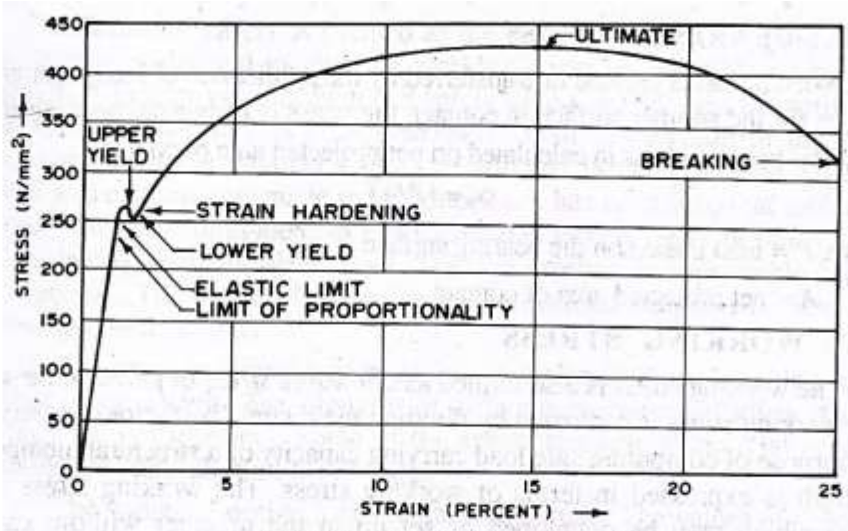
Ex: E250 grade of steel - yield stress 250 N/mm^2

Ultimate stress 410 N/mm^2

The mechanical properties of all the grades a given in table 1:1 of IS 800-2007-P.13

Stress Strain Curve for mild steel:

Stress strain curve is a behavior of material when it is subjected to load. In this diagram stresses are plotted along the vertical axis and as a result of these stresses, corresponding strains are plotted along the horizontal axis. As shown below in the stress strain curve.



STRESS-STRAIN CURVE FOR MILD STEEL

From the diagram one can see the different mark points on the curve. It is because, when a ductile material like mild steel is subjected to tensile test, then it passes various stages before fracture.These stages are;

1. Proportional Limit
2. Elastic Limit
3. Yield Point- Upper yield and loweryield
4. Ultimate Stress Point
5. Breaking Point

(i). Proportional Limit:

It is the region in the strain curve which obeys hooke's law i.e. within elastic limit the stress is directly proportional to the strain produced in the material. In this limit the ratio of stress with strain gives us proportionality constant known as young's modulus. The point OA in the graph is called the proportional limit.

(ii). Elastic Limit:

It is the point in the graph up to which the material returns to its original position when the load acting on it is completely removed. Beyond this limit the material cannot return to its original position and a plastic deformation starts to appear in it. The point A is the Elastic limit in the graph.

(iii). Yield Point or Yield Stress Point:

Yield point in a stress strain diagram is defined as the point at which the material starts to deform plastically. After the yield point is passed there is permanent deformation develops in the material and which is not reversible. There are two yield points and it is upper yield point and lower yield point. The stress corresponding to the yield point is called yield point stress. The point B is the upper yield stress point and C is the lower yield stress point.

(iv) Ultimate Stress Point:

It is the point corresponding to the maximum stress that a material can handle before failure. It is the maximum strength point of the material that can handle the maximum load. Beyond this point the failure takes place. Point D in the graph is the ultimate stress point.

(v). Fracture or Breaking Point:

It is the point in the stress strain curve at which the failure of the material takes place. The fracture or breaking of material takes place at this point. The point E is the breaking point in the graph.

ALLOWABLE STRESS DEIGN OF ANGLE TENSION

Problem:
Find the of strength of a standard angle say ISA 50x50x6 for WSM subjected to load combination of dead load and live load.

Gross area of ISA 50x50x6, A_g = 5.68 cm^2

Working stress method

(a) WSM (Welded) (Clause: 4.2.1 of Page –37 0f IS: 800 –1984)

$A_n = A_1 + A_2.k = (1+k)\ A_g/2 = 1.75 \times 5.68/2 = 4.97\ cm^2\ (A_1 = A_2 = Ag/2)$

$k = \frac{3A_1}{3A_1 + A_2} = 0.75$, where A_1, A_2 are connected and out standing legs

Strength of section = 150 x 4.97 / 1000 = 74660 kN, 74.66kN

(b) WSM (Connected with 5 nos. 12 mm bolts)

$A_1 = 5.68/2 - 1.35 \times 0.6 = 2.03\ cm^2$; $A_2 = 5.68/2 = 2.84\ cm^2$

$k = \frac{3x2.03}{3x2.03 + 2.84} = 0.682$

$\therefore\ T_d = (2.03 + 0.682 \times 2.84)\ 150 = 59500$ kN, 79.5 kN

Problem:

Find the strength of a standard angle say ISA 90x90x8 for WSM subjected to load combination of dead load, live load and wind load

Calculations are in tons. {for students and practicing engineers}

Gross area of ISA 90x90x8, $A_g = 13.79\ cm^2$

(a) WSM (Welded) (Clause: 4.2.1 of Page –37 of IS: 800 –1984)

$A_n = A_1 + A_2.k = (1+k)\ A_g/2 = 1.75 \times 13.79/2 = 12.066\ cm^2\ (A_1 = A_2 = Ag/2)$

$$k = \frac{3A_1}{3A_1 + A_2} = 0.75$$

Strength of section = 1.33x1500 x 12.066 / 1000 = 24.072T

(b) WSM (Connected with 6 nos. 16 mm bolts)

$A_1 = 13.79/2 - 1.75 \times 0.8 = 5.495\ cm^2$; $A_2 = 13.79/2 = 6.895\ cm^2$

$$k = \frac{3x5.495}{3x5.495 + 6.895} = 0.705$$

$\therefore\ T_d = (5.495 + 0.705 \times 6.895)\ 1500/1000 = 15.535T$

Problem:

The tension member of a roof truss consists of a single ISA 100 x 75 x 10 mm thick, connected at the end to a gusset plate with the longer leg vertical with 20 mm diameter rivet. Find the safe tension the member can withstand. Permissible tensile stress may be taken as 150 N/mm^2.

Solution

Diameter of rivet hole = 20 + 1.5 = 21.5 mm

Net effective area provided

Where, A_1 = Net sectional area of the connected leg,

A_2 = Area of the unconnected leg, and

$$K = \frac{3A_1}{3A_1 + A_2}$$

In our case,

$$A_1 = \left(100 - \frac{10}{2}\right)10 - 21.5 \times 10 = 735\ mm^2$$

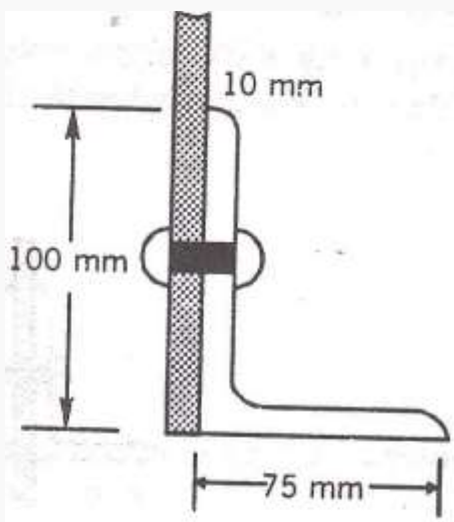
$$A_2 = \left(75 - \frac{10}{2}\right)10 = 700\ mm^2$$

$$K = \frac{3 \times 735}{3 \times 735 + 700} = 0.759$$

$$A_{eff} = 735 + 700 \times 0.759 = 1{,}266\ mm^2$$

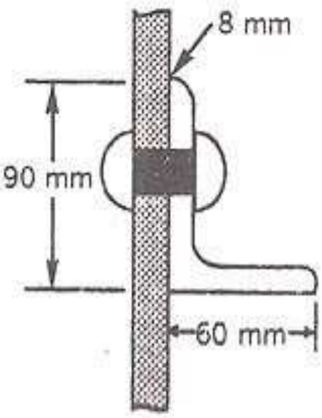
Safe axial tension = A_{eff} x Safe stress

= 1,266 x 150 = 1,89,900 N = 189.9 kN.



Problem:

Design a single angle tension member to sustain a tension of 1,30,000 N. Use 18 mm diameter rivets.



Effective area required $A_{eff} = \frac{1,30,000}{150} = 866.7\ mm^2$

Approximate gross area required $= A_{eff} + 30\ \%$ more

$= 866.7 + (0.3 \times 866.7)$

$= 1,127\ mm^2$

Let us try single angle 90 mm x 60 mm x 8 mm,

Net area of the connected leg $A_1 = (90-4) \times 8 - (19.5 \times 8) = 532\ mm^2$

Area of the outstanding leg $A_2 = (60-4) \times 8 = 448\ mm^2$

$$K = \frac{3A_1}{3A_1 + A_2} = \frac{3 \times 532}{(3 \times 532) + 448} = 0.78$$

Therefore, available effective area $= A_{eff} = A_1 + A_2 K = 532 + 0.78 \times 448 = 881.44\ mm^2$

Safe tension for the member $= 150 \times 881.44 = 1,32,216$ N.

But actual tension in the member is only 1,30,000 N. Hence the design is safe.

CONCEPT OF ALLOWABLE STRESS METHOD

The allowable stress or allowable strength is the maximum stress (tensile, compressive or bending) that is allowed to be applied on a structural material. The allowable stresses are generally defined by building codes, and for steel, and aluminum is a fraction of their yield stress (strength)

$$F_{\alpha} = \frac{F_y}{F.S.}$$

In the above equation, Fa is the allowable stress, Fy is the yield stress, and F.S is the factor of safety or safety factor. This factor is generally defined by the building codes based on particular condition under consideration. Since tension members do not generally buckle, they can resist larger loads (larger Fa) due to small F.S value.

- Allowable Stress Design (ASD) also known as Working Stress Design (WSD) method is based on the principle that stresses developed in the structural members should not exceed a certain fraction of elastic limit.
- This is old method of design which only considers elastic strength of material and hence limits the allowable stresses to a fraction of this limit (e.g. 40-50%).
- All loads are taken as service loads and no factor is applied to increase these services loads.
- The major drawback of this method is that it does not take into account the Plastic and Strain Hardening stages of material, hence, it becomes overly conservative in certain situations, while due to considering load

at service load values only, it produces unsafe results in other situations.

- Further serviceability limits are also not considered in ASD method, which may result in structures which although safe, do not fulfill their intended purpose.
- The main drawback of this method is that it results in an uneconomical section.

The concept of introducing a factor of safety is to make the structure safe to account for the following:

1. The analysis methods are based on assumptions and do not give the exact stresses.
2. Structural members may be temporarily overloaded under certain circumstances.
3. The stresses due to fabrication and erection are not considered in the design of ordinary structures.
4. The secondary stresses may be appreciable.
5. Underestimation of the future live loads.
6. Stress concentrations.
7. Unpredictable natural calamities.

Design of steel beam (ASD, Allowable Stress design)-IS:800-2000

Design requirements

1. Maximum bending stress, f_b must not exceed allowable stress, F_b.
2. Deflection should not exceed allowable limit.
3. Maximum shear stress, f_v shall not exceed allowable shear stress.

Design procedure:

1. Calculate design load.
2. Calculate design moment, M and bending stress, f_b.

3. Select a trial beam size and calculate allowable bending stress, F_b
4. Calculate deflection and check with allowable deflection ratio.
5. Calculate design shear and shear stress, f_v.
6. Calculate allowable shear stress, F_v.

Design of laterally supported beams

1. Calculate the factored load and the maximum bending moment and shear force
2. Obtain the plastic section modulus required

$$Z_{req} = \frac{(M \times \gamma_{mo})}{fy}$$

Select a suitable section for the beam-ISLB, ISMB, ISWB or suitable built up sections (doubly symmetric only). (Doubly symmetric, singly symmetric and asymmetric- procedures are different)

3. Check for section classification such as plastic, compact, semi-compact or slender. Most of the sections are either plastic or compact. Flange and web criteria.

$$\frac{d}{t_w}, \frac{b}{t_f}, \varepsilon = \sqrt{\frac{250}{fy}} = 1$$

4. Calculate the design shear for the web and is given by

$$V_{dp} = \frac{(Av \times fy)}{\sqrt{3} \times \gamma_{mo}} > V_d \; and, V < 0.6V_d$$

5. Calculate the design bending moment or moment resisted by the section (for
plastic and compact)

$$M_d = \beta_p \times Z_p \times f_y / \gamma_{mo}$$

6. Check for buckling
7. Check for crippling or bearing
8. Check for deflectio

Design of Laterally supported Solid Hot Rolled section beams

Design of steel beam (ASD, Allowable Stress design)-IS:800-1984

If the beam is not restrained laterally, the beam can undergo elastic lateral torsional Buckling and can fail due to instability with large lateral deflections, rotations and warping. If the web is too thin, the beam can fail in shear due to diagonal compression. Beams subjected to BM develop compressive and tensile forces and the flange subjected to compressive forces has the tendency to deflect laterally. This out of plane bending is called lateral bending or buckling of beams. The lateral bending of beams depends on the effective span between the restraints, minimum moment of inertia (I_{YY}) and its presence reduces the plastic moment capacity of the section. Beams where lateral buckling of the compression flange are prevented are called laterally restrained beams. Such continuous lateral supports are provided in two ways

i) The compression flange is connected to an RC slab throughout by shear connectors.

ii) External lateral supports are provided at closer intervals to the compression flange so that it is as good continuous lateral support.

Design requirements

1. Maximum bending stress, fb must not exceed allowable stress, F_b.
2. Deflection should not exceed allowable limit.
3. Maximum shear stress, f_v shall not exceed allowable shear stress.

Design procedure:

1. Calculate design load.
2. Calculate design moment, M and bending stress, f_b.

3. Select a trial beam size and calculate allowable bending stress, F_b (see problems)
4. Calculate deflection and check with allowable deflection ratio.
5. Calculate design shear and shear stress, f_v.
6. Calculate allowable shear stress, F_v.

Design of laterally supported beams

The design of laterally supported beams consists of selecting a section based on the plastic section modulus and checking for its shear capacity, deflection, web buckling and web crippling. Most of the equations are available in IS 800 : 2007. The steps are

1. Calculate the factored load and the maximum bending moment and shear force
2. Obtain the plastic section modulus required

$$Z_{req} = \frac{(M \times \gamma_{mo})}{fy}$$

Select a suitable section for the beam-ISLB, ISMB, ISWB or suitable built up sections (doubly symmetric only). (Doubly symmetric, singly symmetric and asymmetric- procedures are different)

3. Check for section classification such as plastic, compact, semi-compact or slender. Most of the sections are either plastic or compact. Flange and web criteria.

$$\frac{d}{t_w}\ ,\ \frac{b}{t_f},\ \varepsilon = \sqrt{\frac{250}{fy}} = 1$$

4. Calculate the design shear for the web and is given by

$$V_{dp} = \frac{(Av \times fy)}{\sqrt{3} \times \gamma_{mo}} > V_d \ and, V < 0.6V_d$$

5. Calculate the design bending moment or moment resisted by the section (for plastic and compact)

$$M_d = \beta_p \times Z_p \times f_y / \gamma_{mo}$$

6. Check for buckling
7. Check for crippling or bearing
8. Check for deflection

A simply supported steel joist of 4m effective span is laterally supported throughout. It carries a total udl of 40kn (service load inclusive of self weight). Dsign an appropriate section using steel grade of Fe_{410}.

For Fe 410 grade of steel, $f_y = 250\ \text{N/mm}^2$

Partial safety factor for material, $\gamma_{mo} = 1.10$

Partial safety factor for load, $\gamma_f = 1.50$

Total uniformly distributed service load = 40 kN/m

Total factored load = 1.5 × 40 = 60 kN

Effective length of beam, $l = 4$ m

Maximum bending moment,

$$M = \frac{(wl)l}{8}$$

$$= \frac{60 \times 4^2}{8}$$

$$= 120\ \text{kNm}$$

Maximum shear force

$$V = \frac{wl}{2}$$

$$= \frac{60 \times 4}{2}$$

$$= 120\ \text{kN}$$

Plastic section modulus required,

$$Z_{pz,\,req} = M\,\frac{\gamma_{m0}}{f_y} = 120 \times 10^6 \times \frac{1.1}{250}$$

$$= 528 \times 10^3\ \text{mm}^3$$

Let us try ISLB 350@ 485.6 N/m

The relevant properties of the section are:

Depth of section, $h = 350$ mm

Width of flange, $b_f = 165$ mm

Thickness of flange, $t_f = 11.4$ mm

Thickness of web, $t_w = 7.4$ mm

Radius at root, $R_1 = 16$ mm

Depth of web, $d = h - (t_f + R_1)$

$= 350 - 2 \times (11.4 + 16)$

$= 350 - 2 \times (27.4)$

$= 295.2$ mm

Moment of inertia, $I_z = 13158.3 \times 10^4$ mm^4

Plastic section modulus, $Z_{pz} = 851.11 \times 10^3$ mm^3

Elastic section modulus, $Z_{ez} = 751.9 \times 10^3$ mm^3

Section classification,

$$\varepsilon = \sqrt{\frac{250}{f_y}}$$

$$= \sqrt{\frac{250}{250}}$$

$$= 1$$

Outstand of flange,

$$b = \frac{b_f}{2}$$
$$= \frac{165}{2}$$
$$b = 82.5 \text{ mm}$$
$$\frac{b}{t_f} = \frac{82.5}{11.4}$$
$$= 7.237 < 8.4$$
$$\frac{d}{t_w} = \frac{295.2}{7.4} = 39.9 < 84$$

Hence, the section is plastic.

Since $\frac{d}{t_w} = 39.89$ less than 67 ($67\varepsilon = 67 \times 1 = 67$), shear buckling check of web will not be required.

(i) Check for Shear Capacity

Design shear force = Maximum shear force

i.e., $V = 120$ kN

Design shear strength of the section,

$$V_d = \frac{f_y}{\sqrt{3}\,\gamma_{m0}}\, h\, t_w$$
$$= \frac{250}{\sqrt{3} \times 1.1} \times 350 \times 7.4 \times 10^{-3}$$
$$= 131.216 \times 350 \times 7.4 \times 10^{-3}$$
$$= 339.849 \text{ kN} > 120 \text{ kN}$$

Hence section is safe shear.

(ii) Check for High/Low Shear

$0.6V_d = 0.6 \times 339.849 = 203.910$ kN > 120 kN

Since $V < 0.6V_d$ the section is of low shear,

(iii) Check for Design Bending Strength

Since section is plastic, $\beta_b = 1$

Design bending strength,

$$M_d = \beta_b Z_{pz} \frac{f_y}{\gamma_{mo}}$$

$$= 1.0 \times 851.11 \times 10^3 \times \frac{250}{1.1} \times 10^{-6}$$

$$= 193.434 \text{ kNm}$$

$$M_d \leq 1.2 Z_{ez} \times \frac{f_y}{\gamma_{mo}} = 1.2 \times 751.9 \times 10^3 \times \frac{250}{1.1} \times 10^{-6}$$

$$= 205.434 \text{ kNm}$$

(iv) Check for Deflection

Permissible deflection, $\delta = \dfrac{l}{300}$

$$= \frac{4 \times 10^3}{300}$$

$$= 13.33 \text{ mm}$$

Maximum deflection,

$$\delta_{cal} = \frac{5}{384} \frac{wl^4}{EI}$$

$$= \frac{5}{384} \times \frac{60 \times 10^3 \times (4 \times 10^3)^3}{2 \times 10^5 \times 13158.3 \times 10^4}$$

$$= 1.899 \text{ mm} < 13.33 \text{ mm}$$

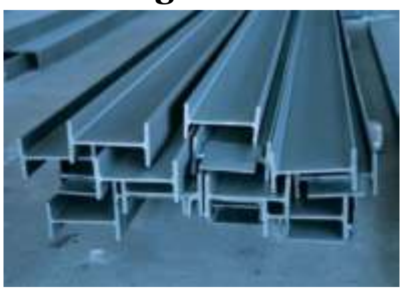
Hence safe.

INDIAN STRUCTURAL STEEL PRODUCTS

India is the 2nd largest steel producer in the world and also approaching towards a full quality regime. To achieve the objective of full quality regime, it is necessary to bring all the relevant Indian steel standards under the ambit of the steel quality control order. In India, Bureau of Indian Standards (BIS) is the National Standards Body, who are engaged in formulation and implementation of National Standards knows as Indian Standards

Rolled beams: ISJB - Indian standard junior beams ISLB - Indian standard lightweight beams ISMB - Indian standard medium weight beams ISWB - Indian standard wide flange beams ISHB - Indian standard heavy weight beams ISSC - Indian standard column section	**Channel Section** ISJC- Indian standard junior channels ISLC- Indian standard light channels ISMC- Indian standard medium channels
T sections ISJT- Indian standard junior T beams ISLT- Indian standard lightweight T beams ISST- Indian Standard **Long** Legged Tee Bars ISMT- Indian standard medium weight T beams	**Rolled bars** ISRO- Indian standard round bars ISSO- Indian standard square bars **Tubular section** ISLT ISMT ISHT

Angle section **T-Section**



I Section **Channel Section** **Tube Section**

Types of structural steel

Corbon steel: Carbon steel is a special type of steel that, as the name suggests, has a higher concentration of carbon than other types of steel. Most types of steel have a relatively low carbon content of about 0.05% to 0.3%. In comparison, carbon steel has a carbon content of up to 2.5%

Fire resistant steel: A steel is generally considered fire-resistant if its strength when heated to such temperatures for short periods of time remains equal to 0.6-0.7 of its strength at room temperature. The greatest resistance to fire — up to 800°C — is obtained in steels that contain boron.

High strength carbon steel: High-carbon steel has a carbon content of 0.60-1.25 wt.% and a manganese content of 0.30 - 0.90 wt.%. It has the highest hardness and toughness of the carbon

High strength tempered steel: tempering are processes that strengthen and harden materials like steel and other iron-based alloys. The process of quenching or quench hardening involves heating the material and then rapidly cooling it to set the components into place as quickly as possible. The process is tightly controlled, with the heating temperature, cooling method, cooling substance and cooling speed all dependent upon the type of material being quenched and the desired hardness. A typical heating range is between 815 and 900 degrees celcius, with extra care being taken to keeping the temperature as stable as possible. Variances in the degree of heat being applied during the process can result in distortion in the resultant metal.

Medium and High strength micro alloyed steel: Microalloyed steel is a type of alloy steel that contains small amount of alloying elements (0.05 to 0.15%), including niobium, vanadium, titanium, molybdenum, zirconium, boron, and rare-earth metals. They are used to refine the grain microstructure or facilitate precipitation hardening

Stainless Steel: Stainless steel is a group of iron-based alloys that contain a minimum of approximately 11% chromium a composition that prevents the iron from rusting and also provides heat-resistant properties. Different types of stainless steel include the elements carbon (from 0.03% to greater than 1.00%), nitrogen, aluminium, silicon, sulfur, titanium, nickel, copper, selenium , niobium, and molybdenum. Specific types of stainless steel are often designated by a three-digit number.

Weathering steel: Weathering steel, often referred to by the genericized trademark COR-TEN steel and sometimes written without the hyphen as corten steel, is a group of steel alloys which were developed to eliminate the need for painting, and form a stable rust-like appearance after several years' exposure to weather.

STEPS INVOLVED IN THE DEIGN PROCESS

General design requirements:

The general design requirements are outlined in Section 3 of IS 800:2007. (P-15)

- The objective of design as 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 unbalanced overall collapse under accidental loading.

Methods of Design

- Clause 3.1.2 from IS800-2007 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.
- Clause 3.1.3 of IS 800:2007 specifies structural design, including design for durability, construction and use should be considered as a whole.
- The realization of design objectives requires compliance with clearly defined standards for materials, fabrication, erection and in-service maintenance.
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- The realization of design objectives requires compliance with clearly defined standards for materials, fabrication, erection and in-service maintenance.

The following methods may be employed for the design of the steel frame work:

1. Simple design
2. Semi-rigid design
3. Fully rigid design and
4. Plastic design

1. Simple Design

This method is based on elastic theory and applies to structure in which the end connections between members are such that they will not develop restraint moments adversely affecting the members and the structures as a whole and in consequence the structure may be assumed to be pin jointed.

2. Semi-rigid design

This method permits a reduction in the maximum bending moment in beams suitably connected to their supports, so as to provide a degree of direction fixity. In the case of triangulated frames, it permits rotation account being taken of the rigidity of the connections and the moment of interaction of members. In cases where this method of design is employed, it is ensured that the assumed partial fixity is available and calculations based on general or particular experimental evidence shall be made to show that the stresses in any part of the structure are not in excess of those laid down in IS : 800-1984.

3. Fully rigid design

This method assumes that the end connections are fully rigid and are capable of transmitting moments and shears. It is also assumed that the angle between the members at the joint does not change, when it is subjected to loading. This method gives economy in the weight of steel used when applied in appropriate cases. The end connections of members of the frame shall have sufficient rigidity to hold virtually unchanged original angles between such members and the members they connect. The design should be based on accurate methods of elastic analysis and calculated stresses shall not exceed permissible stress.

4. **Plastic design**

The method of plastic analysis and design is recently (1935) developed and all the problems related to this are not yet decided. In this method, the structural usefulness of the material is limited up to ultimate load. This method has its main application in the analysis and design of statically indeterminate framed structures. This method provides striking economy as regards the weight of the steel. This method provides the margin of safety in terms of load factor which one is not less than provided in elastic design. A load factor of 1.85 is adopted for dead load plus live load and 1.40 is adopted for dead load, live load and wind or earthquake forces. The deflection under working load should not exceed the limits prescribed in IS : 800-1984.

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(page 26) of IS 800:2007.

- 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 life time 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:

1. Remain fit with adequate reliability and be able to sustain all actions (loads) and other influences experienced during construction and use.
2. Have adequate durability under normal maintenance
3. 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.

LIMIT STATE DESIGN PHILOSOPHY

For achieving the design objectives, the design shall be based on characteristic values for material strengths and applied loads (actions), which take into account the probability of variations in the material strengths and in the loads to be supported. The characteristic values shall be based on statistical data, if available. Where such data is not available, these shall be based on experience. The design values are derived from the characteristic values through the use of partial safety factors, both for material strengths and for loads. In the absence of special considerations, these factors shall have the values given in this section according to the material, the type of load and the limit state being considered.

The reliability of design is ensured by satisfying the requirement

Design action ≤ Design strength

The limit states are classified as

a) Limit state of strength

b) Limit state of serviceability.

The limit states of strength:

The limit states of strength are those associated with failures (or imminent failure), under the action of probable and most unfavorable combination of loads on the structure using the appropriate partial safety factors.

The limit state of strength includes:

a. Loss of equilibrium of the structure as a whole or any of its parts or components.
b. b) Loss of stability of the structure (including the effect of sway where appropriate and overturning) or any of its parts including supports and foundations.
c. Failure by excessive deformation, rupture of the structure or any of its parts or components
d. Fracture due to fatigue
e. Brittle fracture.

The limit state of serviceability:

The limit state of serviceability include

a) Deformation and deflections, which may adversely affect the appearance or effective use of the structure or may cause improper functioning of equipment or services or may cause damages to finishes and non-structural members.

b) Vibrations in the structure or any of its components causing discomfort to people, damages to the structure, its contents or which may limit it functional effectiveness. Special consideration shall be given to systems susceptible to vibration, such as large open floor areas free of partitions to ensure that such vibrations are acceptable for the intended use and occupancy

c) Repairable damage or crack due to fatigue.

d) Corrosion, durability

e) e) Fire.

Working stress method	Ultimate load method	Limit state method
• It is based on *elastic theory* (i.e. attainment of the initial yielding forms design criteria for the members in this approach) • Safety is considered in terms of *Factor of Safety* which is applied to the material strength	• It is based on *plastic theory* (i.e. steel possess a reserve strength beyond its yield stress due to strain hardening upto ultimate stress which is utilized in this approach) • Safety is considered in terms of *Load factor* which is applied to the external load	• It is developed after Ultimate load method & is based on *plastic theory.* • Safety is considered in terms of *partial safety factor* which is applied to both material strength & external load.

TYPE OF LOADS ON STRUCTURES AND LOAD COMBINATIONS

LOADS AND FORCES :(Clause 3.2 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

- Dead loads
- Imposed loads (live load, crane load, snow load, dust load, wave load, earth pressures, etc.)
- Wind loads; (d) Earthquake loads
- Erection loads
- Accidental loads such as those due to blast, impact of vehicles, etc.
- Secondary effects due to contraction or expansion resulting from temperature changes, differential settlements of the structure as a whole or of its components, eccentric connections, rigidity of joints differing from design assumptions.

LOADS ON STRUCTURES:

- Dead Load: [I.S. 875 Part-I]-Code of practice for Design loads (dead load)

  Dead loads are the permanent loads acting on the structure including the self-weight of the section.

- Live Load: [I.S. 875 Part-II] -Code of practice for Design loads (imposed load)

  It is an imposed load in structure due to people, furniture, movable objects etc. Based on utility of the structure the values are given in [I.S 875 Part-II]

  Example:
  For Residential Buildings – 2 KN/m^2
  For Commercial Buildings – 3 KN/m^2

- Wind Load [I.S 875 Part-III] -Code of practice for Design loads (wind load)
- Snow Load [I.S 875 Part-IV] -Code of practice for Design loads (snow load)
- Seismic Load (or) Earth quake Load [I.S 1893-2002]
- Accidental Loads
- Errection Loads
- Temperature effects

LOAD COMBINATIONS:

[I.S 875 Part-V] -Code of practice for Design loads (Special Loads and Combinations)

Load combinations for design purposes shall be those that produce maximum forces and effects and consequently maximum stresses and deformations. The following combination of loads with appropriate partial safety factors as given in Table 4 of IS 800:2007 may be considered.

a) Dead load + imposed load
b) Dead load + imposed load + wind or earthquake load
c) Dead load + wind or earthquake load
d) Dead load+ erection load.

The effect of wind load and earthquake loads shall not be considered to act simultaneously. The load combinations are outlined in detail in Clause. 3.5 of IS 800:2007.

CHARACTERISTICS OF LOAD:

It is designed as the action of the load which are not expected more than five percentage probability during the life of the structure.

1. Partial safety factor for loads for limit state 'γf' is given in table 4 [I.S 800-2007]

2. Partial safety factor for material is given in table 5 [I.S 800-2007]

Table 4 Partial Safety Factors for Loads, γ_f, for Limit States

(*Clauses* 3.5.1 *and* 5.3.3)

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)[2]	—	—	1.5	—	1.0	—	—	1.0
DL+ER	1.2 (0.9)[2]	1.2	—	—	—	—	—	—	—
DL+LL+AL	1.0	0.35	0.35	—	1.0	—	—	—	—

Table 5 Partial Safety Factor for Materials, γ_m

(*Clause* 5.4.1)

Sl No.	Definition	Partial Safety Factor	
i)	Resistance, governed by yielding, γ_{m0}	1.10	
ii)	Resistance of member to buckling, γ_{m0}	1.10	
iii)	Resistance, governed by ultimate stress, γ_{m1}	1.25	
iv)	Resistance of connection:	*Shop Fabrications*	*Field Fabrications*
	a) Bolts-Friction Type, γ_{mf}	1.25	1.25
	b) Bolts-Bearing Type, γ_{mb}	1.25	1.25
	c) Rivets, γ_{mr}	1.25	1.25
	d) Welds, γ_{mw}	1.25	1.50