CHAPTER – 1

INTRODUCTION

Design of a steel structure is divided two type based on

Functional design

The first consists in planning the building to serve its requirements taking into account ventilation, lighting, authentic view etc.

Structural design

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.

COMMON STEEL STRUCTURES

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

- ✓ Roof trusses for factories, cinema halls, auditoriums etc
- ✓ Trussed bents, crane girders, columns etc., in industrial structures.
- ✓ Roof trusses and columns to cover platforms in railway stations and bus stands
- ✓ Single layer or double layer domes for auditoriums, exhibition
- ✓ Plate girder and truss bridges for railways and roads.
- ✓ Transmission towers for microwave and electric power.
- ✓ Water tanks,
- ✓ Chimneys etc.

ADVANTAGES AND DISADVANTAGES OF STEEL STRUCTURES

The advantages of steel over other materials for construction are:

- ✓ 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,

- ✓ It has assured quality and high durability.
- ✓ Speed of construction is another important advantage of steel structure. Since standard section of steel are available which can be prefabricated in the workshop/site, they may be kept read by the time the site is ready and the structure erected as soon as the site is ready. Hence there i lot of saving in construction time.
- ✓ Steel structures can be strengthened at any later time, if necessary. It needs just ditional sections
- ✓ By using bolted connections, steel structures can be easily dismantled and transported to other
- ✓ If joints are taken care, it is the best water and gas resistant structure. Hence can sites quickly. Making water tanks also.
- ✓ Material is reusable.

The disadvantages of steel structures are:

- ✓ It is susceptible to corrosion
- ✓ Maintenance cost is high.
- ✓ Steel members are costly.

1.3 TYPES OF STEEL

Steel is an alloy of iron and carbon. Apart from carbon by adding small percentage of manganese, sulphare, phosphorus, chrome nickel and copper special properties can be imparted to iron and a variety steels can be produced. The effect of different chemical constituents on steel are generally as follows

(1) Increased quantity of carbon and manganese imparts higher tensile strength and yields properties but lower ductility, which is more difficult to weld.

(ii) Increased sulphur and phosphorus beyond 0,06 percent imparts brittleness, affects weld ability and fatigue strength.

(iii) Chrome and nickel impart corrosion resistance property to steel. It improves resistance to high temperature also,

1.4 PROPERTIES OF STRUCTURAL STEEL

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

1. Physical Properties
2. Mechanical Properties

(1) **Physical Properties**

Irrespective of its grade physical properties of steel may be taken as given below (clause 2.2.4 of 15 800-2007):

- Unit mass of steel, p=7850 kg/m².
- Modulus of elasticity, E-20x10¹ N/mm²
- Poisson's ratio, -0.3.
- Modulus of rigidity, G=0.769 x 10 N/mm².
- Coefficient of thermal expansion, a, 12 x 10°C.

2. **Mechanical Properties**

The following are the important mechanical

- Yield stress f_y
- The tensile or ultimate stress f_u
- The maximum percentage elongation on a standard gauge length
- Notch toughness

ROLLED STEEL SECTIONS

Various types of rolled steel sections manufactured are listed below:

1. Rolled steel 1-sections (Beam sections)
2. Rolled steel Channel sections

3. Rolled steel Angle sections
4. Rolled steel Tee sections
5. Rolled steel Bars
6. Rolled steel Tubes
7. Rolled steel Plates
8. Rolled steel Flats
9. Rolled steel Sheets and Strips.

Rolled Steel l-section

The following five series of rolled steel I-sections are manufactured in India:

(a) Indian Standard Junior beams-ISJB

(b) Indian Standard Light Beams - ISLB

(e) Indian Standard Medium Beams-ISMB

(d) Indian Standard Wide-flange Beams-ISWB

(e) Indian Standard Heavy Beams - ISHB.

These sections are designated by the series to which they belong, followed by depth (in mm) and weight per meter run e.g. ISMB 500 @ 0.852 kN/m. It may not matter much if weight per meter length is written in case of ISJB, ISLB and ISMB sections, since there is only one standard section for a specified depth. But in case of ISWB and ISHB sections weight per unit length should always be special since for the same depth in these series more than one section are available with different weight properties e.g. ISWB 600 @1423 kN/m ISWB 600 1312 kN/m ISHB 450 0.855 kN/m, ISHB 450 0.907 kN/m

Rolled Steel Channel Sections

These sections are classified into the following four series:

(a) Indian Standard Junior Channel – ISIC
(b) Indian Standard Light Channel-ISLC
(c) Indian Standard Medium weight Channel-ISMC
(d) Indian Standard Special Channel - ISSC.

Rolled steel channel sections are designated by the series to which they belong, followed by depth (in mm) and weight (in kN/m), e.g. ISMC 300 @ 0.351 kN/m.

Rolled Steel Angle Sections

These are classified into the following two series:

(a) Indian Standard Equal Angle - ISA

(b) Indian Standard Unequal Angle -ISA.

Thickness of legs of equal and unequal angles are same. Rolled steel equal and unequal angles are designated by their series name ISA followed by length and thickness of legs e.g: ISA 150 150, 12 mm thick ISA 150 115, 10 mm thick

Rolled Steel Tee Sections

Following five series of rolled steel sections are available.

(a) Indian Standard Normal Tee bars-ISN

(b) Indian Standard Heavy flanged Tee bars - ISHT

(c) Indian Standard Special Legged Tee bars-ISLT

(d) Indian Standard Light Tee bars-ISLT

(e) Indian Standard Junior Tee bats-ISJT.

These rolled steel sections are designated by the series to which they belong followed by depth an weight per meter length, eg: ISNT 60@53 N/m

As per IS 808-1984, the following T-sections have also been adopted:

(a) Indian Standard Deep legged Tee bars-ISDT

(b) Indian Standard slit Medium weight Tee bars-ISMT

(c) Indian Standard slit Heavy Tee bars from 1-sections-ISHT.

Rolled Steel Bars

Rolled steel bars are classified into the following two series:

(a) Indian Standard Round bars-

(b) Indian Standard Square bars-ISSQ.

ISRO Rolled steel bars are designated by ISRO followed by diameter in case of round bars and ISSQ followed by side width in case of square bars eig. ISRO 16 ISRO 20.

Rolled Steel Tubes

These sections are designated by their nominal base sizes. In each size there are three classes, namely Light, Medium and Heavy. The difference is due to difference in their thicknesses. Hence their cross sectional properties are also different. For example, a 40 mm tube has 3 types and their sectional proper ties are as given below:

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, 120, 155, 400, 450, 500, 560, 630, 710, 800, 900, 1000, 1100, 1250, 1400, 1600, 1800, 2000, 2200, 2500 mm.

These plates are designated by 15P1 followed by length, width and thickness e.g. ISPL 2000-1000-6

Rolled Steel Strips

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, 09, 10, 11, 12, 14, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.2, 3.5, 4.0, 4.5 mm

It may be noted that thickness of strips is less than 5 mm. Rolled steel strip is designated as ISST, followed by width and thickness e.g. ISST 250x25 mm.

Rolled Steel Flats

Plats 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.

SPECIAL CONSIDERATIONS IN STEEL DESIGN

The following special considerations are required in the steel design:

1. Size and Shape

2. Buckling

3. Minimum Thickness

4. Connection Designs.

1.7 LOADS

1. Dead Load (DL)

2. Imposed load (IL)
3. Wind Loads (WL)
4. Earthquake Loads (EL)
5. Erection Loads (ER)
6. Accidental Louis (AL)

Secondary Effects

Dead Load

Dead loads include the weight of all permanent construction. For example weight of roofs, floors, floor finishes, wall, beams, columns, footing etc. constitute dead load. These loads may be assessed by estimating the quant and then multiplying it with unit weight.

Since, without design, the self weight is not known, this is estimated from referen

Imposed Load

IS 800-2007 groups the following loads as imposed loads

1. Live load
2. Crane load
3. Snow load
4. Dust load
5. Hydrostatic and earth pressure
6. Impact load
7. Horizontal leads on parapets and balustrades

Live Load (LL)

The loads which keep on changing from time to time are called live loads. For examples of such loads in a building are the weight of the persons, weight of movable person, dust loads and weight of furniture.

Residential buildings-dwelling houses, hotels, hostels, boiler rooms and plant rooms, garage, Educational buildings, Institutional buildings, Assembly buildings, Business and office buildings

Crane Load (CL)

These loads included loads from cranes and other machines acting on the structure. The loads may be taken as per manufacture suppliers data. in the absence of specific indicat they may be taken as given below (15 800-2007, clause 35.4)

SNOW LOAD

IS 875 (part 4) deals with snow loads on roof of the buildings. This load is to considered for the buildings to be located in the regions where snow is likely to fall. The snow load is act vertically downward.

Dust Load

The load is calculated in the industrial area.

example: steel plant, cement industry etc.

Wind Load

The force exerted by the horizontal component of wind is to be considered in sign of building, towers etc. The wind force depends upon the velocity of wind, shape, size and hight of building

Earthquake Loads

Earthquake shocks cause movement of foundation of structures. Due to additional forces develop on superstructure. The total vibration caused by earthquake may be re into three mutually perpendicular directions, usually taken as vertical and two horizontal directions. The movement in vertical direction does not cause significant forces in superstructure. But move horizontal direction needs special consideration.

Erection Loads

Prefabricated or precast members are subjected to different types of supp different types of loads during erection compared to the types of supports and types of loads action. It is the responsibility of engineer to see that the structure or part of the structure do not fabrication.

Accidental Loads

(i) Impact and collision

(ii) Explosions and

(iii) Fire.

IMPACT AND COLLISIONS

Common sources of impacts are Vehicles, Dropped object from cranes, lifts ,Crane/ lift failures

EXPLOSIONS

The following types of explosions are to be looked into the designs:

Internal gas explosion, External gas explosion, Boiler failures and High explosions (dynamite).

IS 875 (part 5) gives codal requirements for internal gas explosions. The last type of exp above is to be considered in designing air raid shelters. H) FIRE: IS 875 (part 5) specify that extraordinary loads during fire on escape routes and

Secondary Effects

The following types of secondary effects should be looked into the

Differential settlement of foundations, Differential shortening of columns, Eccentric connections, Rigidity of joints differing from design assumptions.

LOAD COMBINATIONS

A judicious combination of the loads is necessary to ensure the required safety and economy 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 combination of various loads.

The recommended load combinations by IS 875 are as given below

1. DL
2. DL+ IL+EL
3. DL+IL+TL
4. DL+WL
5. DL+EL+TL
6. DL+EL
7. DL+IL+WL+TL
8. DL-IL EL TL

Where

DL = Dead Load

IL = Imposed Load

EL=Earthquake Load

WL Wind Load

TL = Temperature Load

Design Philosophy

- ✓ Working stress method
- ✓ Limit state method
- ✓ Ultimate load method

CHAPTER – 2

BOLTED CONNECTIONS

As steel structures are to be formed by connecting available standard sections there is need for the following connections:

(a) Different sections to form the required composite section of a member (e.g. connection angles, channels, 1-sections etc.)

(b) Different members at their ends (e.g. secondary beams to main beams, beams to columns to footing or members of trusses etc.).

The design of connections is very important because the failure of joint is sudden and catastrophic.

The following three types of connections may be made in steel structures:

(a) Riveted

(b) Bolted

(c) Welded.

RIVETED CONNECTION

Riveting is a method of joining together pieces of metal by inserting ductile metal pins called rivets into holes of pieces to be connected and forming a head at the end of the rivet to prevent each from coming out.

Rivet holes are made in the structural members to be connected by punching or by drilling rivet hole is kept slightly more (1.5 to 2 mm) than the size of rivet. After the rivet holes in are matched, a red hot rivet is inserted which has a shop made head on one side and the length is slightly more than the combined thicknesses of the members to be connected. Then hole rivet at shop head end, hammering is made. It results into expansion of the rivet to complete rivet hole and also into formation of driven head. Desired shapes can be given to the drive riveting may be in the workshops or in the field.

Riveting has the following disadvantages:

- ✓ It is associated with high level of noise pollution.
- ✓ It needs hearing the rivet to red hot.
- ✓ Inspection of connection is a skilled work
- ✓ Removing poorly installed rivets is costly
- ✓ Labour cost is high

BOLTED CONNECTIONS

A bolt is a metal pin with a head formed at one end and shank threaded at the other in order to receive a nut. Bolts are used for joining together pieces of metals by inserting them through holes in the metal and tightening the nut at the threaded ends. Figure 3.2 shows a typical bolt.

Bolts are classified as:

(a) Unfinished (Black) Bolts
(b) Finished (Turned) Bolts
(c) High Strength Friction Grip (HSFG) Bolts.

Unfinished/Black Bolts

These bolts are made from mild steel rods with square or hexagonal bead. The shank is left unfinished rough as rolled. Though the black bolts of nominal diameter (diameter of shank) of sizes 12, 16, 20, 22, 27,30 and 36 mm are available, commonly used bolt diameters are 16, 20, 24, 30 and 36 mm. These be are designated as M16, M20, M24, etc. IS 1364 (part 1) gives specifications for such bolts. In structure elements to be connected holes are made larger than nominal diameter of bolts. As shanks of black be are unfinished, the bolt may not establish contact with structural member at entire zone of contact surface Joints remain quite loose resulting into large deflections. The yield strength of commonly used black bear is 240 N/mm² and ultimate strength 400 N/mm.

These bolts are used for light structures under static load such as trusses, bracings and also for temporary connections required during erections.

Finished/Turned Bolts

These bolts are also made from mild steel, but they are formed from hexagonal rods, which are finish by turning to a circular shape. Actual dimension of these bolts are kept 1.2 mm to 1.3 mm larger than the nominal diameter. As usual the bolt hole is kept 1.5 mm larger than the nominal diameter. Hence tolerance available for fitting is quite small. It needs special methods to align bolt holes before bolting, a connection is tighter, it results into much better bearing contact between the bolts and holes. The bolts are used in special jobs like connecting machine parts subjected to dynamic loadings.

High Strength Friction Grip (HSFG) Bolts

The HSFG bolts are made from high strength steel rods. The surface of the shank is kept unfinished in the case of black bolts. These bolts are tightened to a proof load using calibrated wrenches. Hence they grip the members tightly. In addition nuts are provided by using clamping devices. If the joint subjected to shearing load it is primarily resisted by frictional force between the members and washer .The shank of the bolt is not subjected to any shearing. This results into no-slippage in the joint. Hen such bolts can be used to connect members subjected to dynamic loads also. The successful introduction of HSFG bolt resulted into replacement of rivets. IS 3747 specifies various dimensions for such bolt and for their washers and nuts. Commonly available nominal diameter of HSFG bolts are 16, 20, 24, and 36 mm.

3.3 CLASSIFICATION OF BOLTS BASED ON YVER GE LOAD TRANSFER

On the bass of load transfer to the connection bolt may be classified

1. Bearing Type
2. Friction group type

Unfinished (black) belts and finished (turned)bolts belong to bearing type since they transfere shear force from one member to other member by bearing, where HSFG bolts belongs to friction grip type since they transfer shear by friction

Advantages of USFG Haly Over Beaving Type Hals

Iroald have the following advantages over wants padoled tea

1. intrat id Te, no stip takes place in the joint

2 As a transfer is madily by friction the balls are not endijeled to dearing

1 thigh static swength due to high fional resistance and bearing

4: High fatigue emngth or nots are prevented from bothing and unces comentatome avoided die is friction grip

3 Smaller number of bolt result into analer sizes of pussit plates

The following the disadvantages of HSFG bolts

1. Material cost is high
2. The special attention is to be give to workmanship especially to give them right amount of tension.

ADVANTAGES AND DISADVANTAGES OF BOLTED CONNECTIONS

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

1. Making joints is noiseless
2. Do not need skilled labor
3. Needs skill labour
4. Connections can be made quickly.
5. Structure can be put immediately.
6. Working area of the field is less

7. Alternations , If any can be done easily.

TERMINOLOGY

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

1. pitch of the bolts it is the centre to centre spacing of the bolts in a row, measured along the direction of load. It is shown as 'p'.

Gauge distance 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.)

Edge Distance (e) It is the distance of centre of bolt hole from the adjacent edge of plate.

End distance (e’) It is the distance of the nearest bolt hole from the end of the plate

Staggered Distance: It is the centre to centre distance of staggered bolts measured obliquely of the member as shown in Fig.

IS 800-2007 SPECIFICATIONS FOR SPACING AND EDGE DISTANCES OF

TYPES OF BOLTED CONNECTIONS

Types of joints may be grouped into the following two

(a) Lap joint

(b) Butt jouit

(a) Lap Joint

TYPES OF ACTIONS ON FASTENERS

Depending upon the types of connections and loads, bolts are subjected to the following types c 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.

ASSUMPTIONS IN DESIGN OF BEARING BOLTS

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

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,

CHAPTER – 3

TENSION MEMBER

Introduction

A structural member subjected to tensile force applied at its end is called tension member.

It is also called tie member. The member is connected so that the eccentricity of the connection and bending stress on the member are negalted.

If some eccentricity will exist due to either member non perfectly are connected then bending stress is consider in the design.

Different shape of tension member

Example of tension member

- ✓ Truss in the building and bridge
- ✓ Suspension bridge
- ✓ Industrial building

Failure of tension member

Failure due to yielding of gross section

Consider the deformation of the member in longitudinal direction may take place before in fracture and making the structure unserviceable.

Design strength due to yielding of gross plate

$$T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$$

A_g = Gross area of the cross section

f_y = Yield stress of the material

γ_{m0} = 1.10 (partial safety factor)

Failure due to rupture of critical section

The rupture of the member, when the net cross section of the member is reaches the ultimate stress and the design strength due to rupture of critical section.

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{ml}}$$

CHAPTER - 4

COMPRESSION MEMBER

Introduction

A member which carries a axial load is known as compressive member. Example: column, strut, frame, truss.

Slenderness ratio

Slenderness ratio of a column is defined as the ratio of effective length to corresponding radius of gyration of the section.

Mathematically, Slenderness ratio $= \frac{l_e}{r} = \frac{KL}{r}$

Where, L= actual length of compressive member

$l_e = KL$, effective length

r = appropriate radius of gyration

Design of compressive stress and strength

The design compressive strength *Pd*, of a member is given by:

$P < Pd$

Where,

$Pd = A_e f_{Cd}$

Where,

A. = effective sectional area

f_{Cd} = design compressive stress,

The design compressive stress, f_{Cd}, of axially loaded compression members shall be calculated using the following equation:

$$f_{cd} = \frac{f_y/\gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]} = \chi f_y/\gamma_{m0} \leq f_y/\gamma_{m0}$$

$$\phi = 0.5\left[1 + \alpha(\lambda - 0.2) + \lambda^2\right]$$

λ = Non-dimensional effective slenderness ratio

$$= \sqrt{f_y/f_{cc}} = \sqrt{f_y(KL/r)^2/\pi^2 E}$$

f_{cc} = Euler's buckling stress

$$f_{cc} = \frac{\pi^2 E}{(KL/r)^2}$$

$\frac{KL}{r}$ = Effective slenderness ratio or ratio of effective length 'KL' to appropriate radius of gyration 'r'. It should be check different end condition of compressive member refere the page IS 800-2007 (page number- 45)

E = young modulus

α = Imperfection factor Table 8 IS code 800-2007 (page number -35)

χ = stress reduction factor, calculate from table number 8 IS 800-2007

$$= \frac{1}{\phi + \left[\phi^2 - \lambda^2\right]}$$

γ_{m0} = partial safety factor for material strength

NOTE

The design compressive stress, f_{Cd}, of axially loaded compression members shall be calculated using by taking slenderness ratio '$\frac{KL}{r}$'of compressive member and value 'f_y' value of the member and also taking the buckling class of the member, from table 8 IS 800-2007.

Note:
Buckling class should be check by using the IS 800-2007 (page number-44).