LECTURE NOTE

ON

STRUCTURAL DESIGN-II **(TH.2)**

5TH SEMESTER IN CIVIL ENGG.

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Common steel structures

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 & bus stands.

4- Single layer or double layer domes for auditoriums, exhibition halls, indoor stadiums etc.

5- Water tanks.

6- Chimneys.

Advantages.

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- Steel structures can be strengthened at any later time, if necessary. It needs just welding additional sections.

4- By using bolted connections, steel structures can be easily dismantled and transported to other sites quickly

5- If joints are taken care, it is the best water and gas resistant structure hence can be used for making water tanks.

7- Material is reusable.

Disadvantages

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

Types of steel

Steel is an alloy of iron and carbon
- Apart from carbon by adding small percentage of manganese, sulphur, phosphorus, chrome nickel and copper special properties can be imparted to iron and a variety of steel can be produced.

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 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 $\alpha_t = 12 \times 10^{-6} / ^\circ C$

(iii) Mechanical properties

a - Yield stress fy
b - The tensile or ultimate stress fu
c - The maximum percentage elongation on a standard gauge length
d - Notch toughness.

Rolled steel sections

→ Many steel section are readily available in the market and are in frequent demand such steel sections are known as Regular Steel sections.

→ Some steel sections are not in use commonly, but the steel mills can roll them if orders are placed, such steel sections are known as special sections.

TYPES

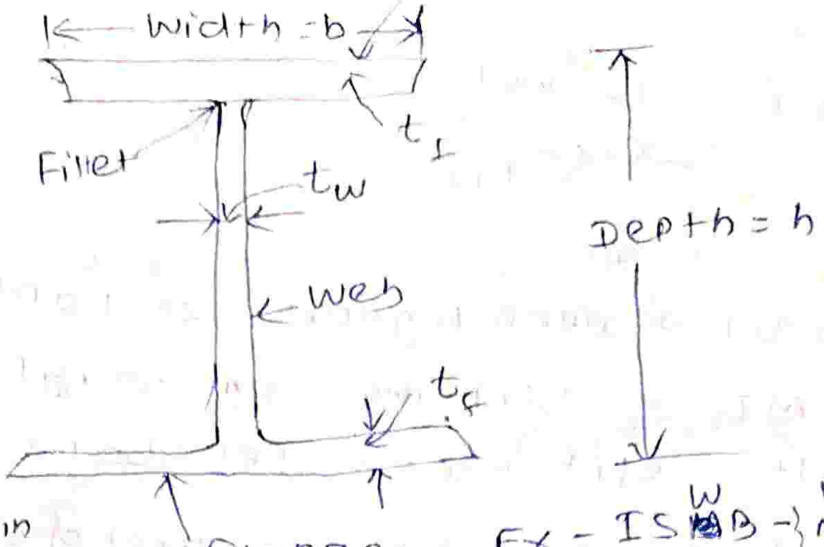
1 - Rolled Steel I sections (Beam Sections)
2. Rolled steel channel sections
3 - Rolled steel angle sections
4 - Rolled steel Tee sections
5 - Rolled steel bars
6 - Rolled steel tubes.
7 - Rolled steel plates
8 - Rolled steel flates
9 - Rolled steel sheets and strips.

1 - Rolled steel I section

a - Indian standard Junior beams - ISJB
b - Indian standard Light beams - ISLB
c - Indian standard medium Beams - ISMB
d - Indian standard wide - flange beam - ISWB

e - Indian standard Heavy Beams - ISHB

I section

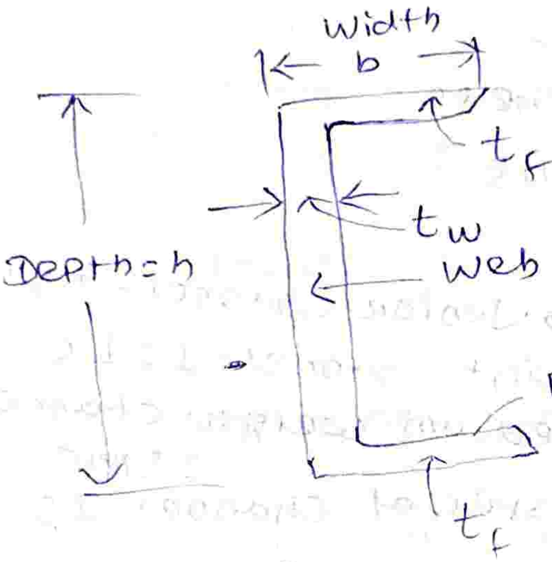


EX - ISWB → } Wt per mt length should specified
ISHB

can't - ~~ISLB~~, ~~ISJB~~

EX
ISWB 600 @ 1.423 KN/m
(Depth in mm) (weight)

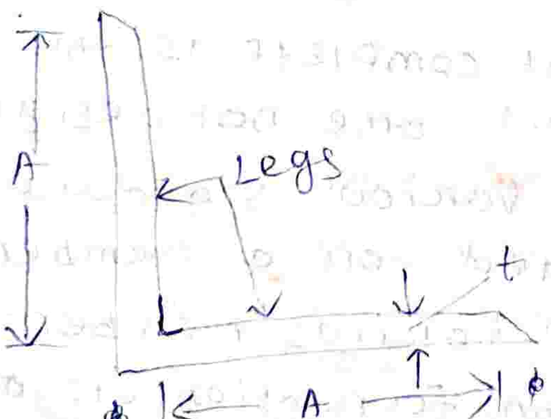
Channel section

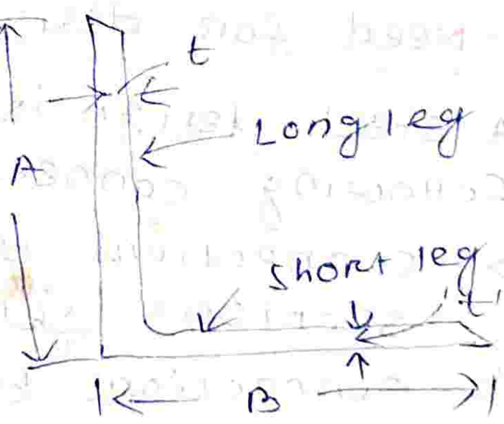


same except ISWB

EX
ISMC 300 @ 0.351 KN/m
(Depth in mm) (weight)

Angle section ISA

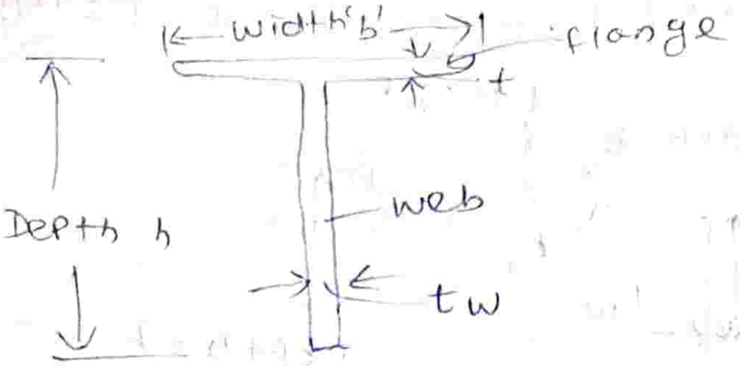




a - Rolled steel Equal angle

b - Rolled steel unequal angle

1 - Indian standard Equal Angle - ISA - ISA 150x150x12
2 - " " unequal " - ISA 150x115x



ISDT - Deep legged Tee bars
ISMT - slit medium weight Tee bars
ISHT - slit Heavy Tee bars

Special considerations in steel design

1 - Size and shape
2 - Buckling
3 - Minimum Thickness
4 - connection Designs

Channel section

1 - Indian standard ~~join~~ Junior Channel - ISJC
2 - Indian standard Light channel - ISLC
3 - Indian standard Medium weight channel - ISMC
4 - Indian standard special channel - ISSC

1 - Size and shape

4 - Need for design of connection

A steel design is not complete if the following connections are not designed
a - connections betn various standard sections selected for a member
b - connections betn various member (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 connection.

Now a days riveted connection is used more than welded connection.

Loads for design

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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.

a - Dead loads (DL)

Dead loads include the weight of all permanent construction

Ex

In a building weight of roofs, floors, floor finishes, wall, beams, columns, footing architectural finishing materials etc constitute dead load.

b - Imposed loads

1 - Live load
2 - crane load
3 - Dust load
4 - snow load
5 - impact load
6 - Hydrostatic & earth pressure.

2nd chapter BOLTED CONNECTIONS

- The choice of type of fasteners depend on
  - → Connection strength required
  - → space limitations of the connections.
  - → Available technicians to fabricate & erect the structure
  - → service conditions & finally the total cost of installation.

The fasteners serve essentially the same function in transferring loads from one component to another.

The connections are named after the type of fasteners used.

→ In bolted connection bolts and nuts are used.

Classification of bolts

There are three types of bolts are use

1- Unfinished (Black) bolts
2- Turned (Finished) bolts
3- High strength Friction Grip (HSFG) bolts.

Advantages of bolted connections

1- There is silence in preparing bolted connection. (In riveting hammering is done, the hammer causes noise)

2- There is no risk of fire in bolted connection, (In riveting red hot is produced & there is risk of fire)

3- The bolted connections may be done quickly in comparison to the riveting

4- Through the cost of bolts is more than the cost of rivets, the bolted connections are economical to use them than rivets because less persons are required for installation, and the work proceeds quickly.

5- The bolted connections facilitate the erection because of ease ~~of~~ with which these connections can be done

Disadvantages of bolted connection

1- If bolted connections become loose, their strength reduces considerably.

2- The unfinised bolts are not uniform in diameter and they have less strength

3- The bolted connections have less strength when they are subjected to axial tension, because area at root of thread is less.

4- Generally, the diameter of hole is kept 1.6 mm more than the nominal diameter of black bolt. The bolt doesn't fill the hole and there remains a clearance in bolted connections.

Classification of bolts based on type of load transfer

On the basis of load transfer in the connection bolts may be classified as

a- Bearing type

b- Friction grip type

→ Unfinished (black) bolts and ~~[illegible]~~ finished (turned) bolts belong to bearing type since they transfer shear force from one member to other member by bearing

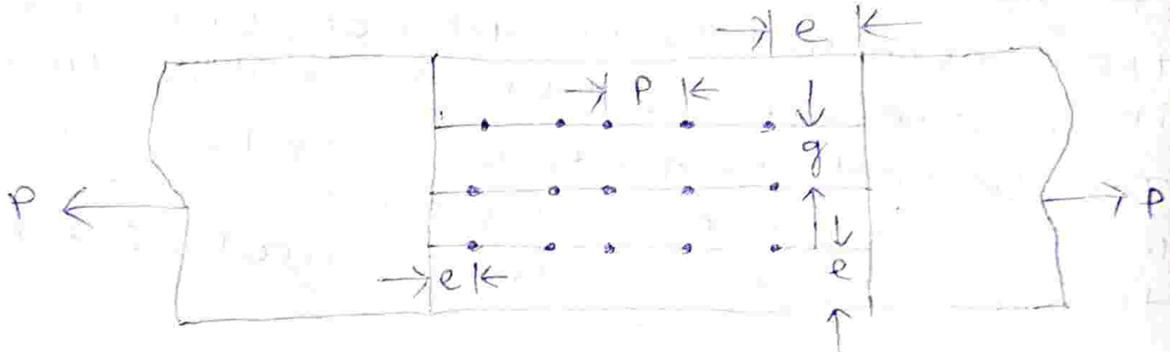
→ HSFG bolts belong to friction grip type since they transfer shear by friction.

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'.

2- Gauge Distance (g)

It is the distance betⁿ the two consecutive bolts of adjacent rows and is measured at right angles to the direction of load



3- Edge Distance (e)

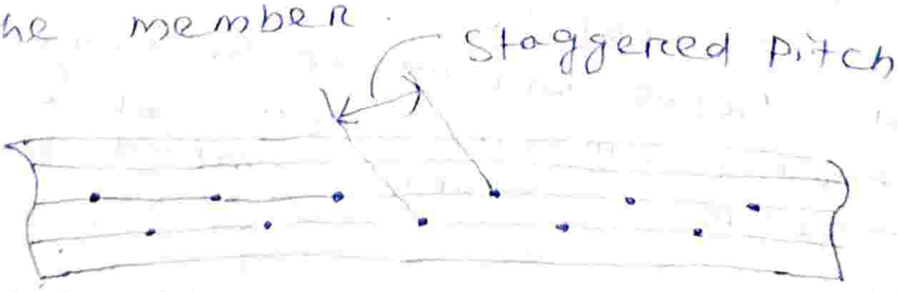
It is the distance of centre of bolt hole from the adjacent edge of plate.

4- End distance (e')

It is the distance of the nearest bolt hole from the end of the plate.

5- Staggered Distance

It is the centre to centre distance of staggered bolts measured obliquely on the member.



IS 800-2007 specifications for spacing and Edge Distance of bolt holes.

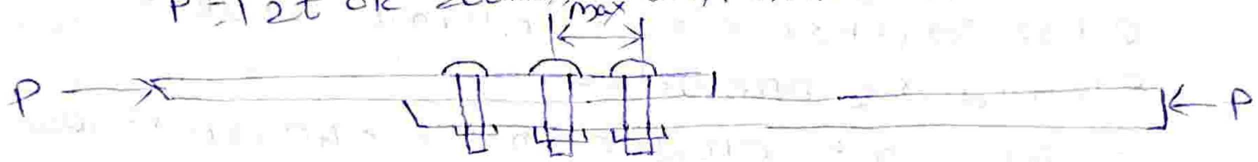
1- Pitch 'p' shall not be less than 2.5d, where d is the nominal diameter of bolt

2- Pitch 'p' shall not be more than

a- 16t or 200m, which ever is less, in case of tension member

b- 12t or 200mm, whichever is less, in case of compression members where 't' is the thickness of thinnest member

P = 12t OR 200mm, whichever is less



c- Incase of staggered pitch, pitch may be increased by 50% of values specified above provided gauge distance is less than 75 mm

3- Incase of butt joints max pitch is to be restricted to 4.5d for a distance from of 1.5 times the width of plate from the butting surface.

4- The gauge length 'g' should not be more than 100+4t or 200mm whichever is less

5- minimum edge distance shall not be

a- Less than 1.7 x hole dia in case of shear -ed or hand flame cut edges

b- Less than 1.5 x hole diameter in case of Rolled, machine flame cut, sawn and planed edges.

6- Maximum edge distance (e) should not exceed a - $16t\epsilon$, where $\epsilon = \sqrt{\frac{250}{fy}}$ and t is the thickness of thinner outer plate.

b - $40 + 4t$ where t is the thickness of thinner connected plate.

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 of max edge distances tacking rivets should be provided

i - At 32t or 300mm, whichever is less, if plates are not exposed to weather

ii - At 16t or 200mm, 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 1000mm, if it is tension member

b - Not exceeding 600mm, if it is compression member

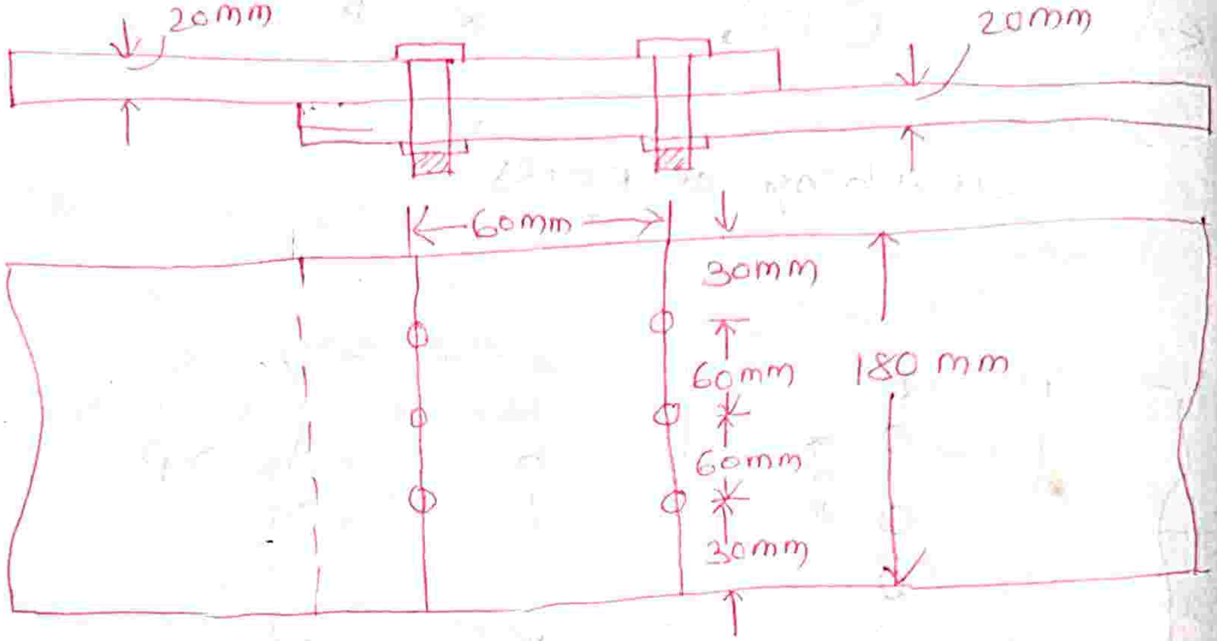
Types of bolted connections

1 - Lap joint

2 - Butt joint

1 - It is the simplest type of joints. In this the plates to be connected overlap one another

PRB Find the efficiency of the lap joint. M20 bolts of grade 4.6 and Fe 410 plates are used.



Solⁿ

For M20 bolts of grade 4.6

diameter of bolt, $d = 20mm$

diameter of bolt hole, $d_0 = 22mm$

ultimate strength $f_{ub} = 400 MPa$

partial safety factor $\gamma_{mb} = 1.25$

ultimate stress, $f_u = 410 MPa$

partial safety factor, $\gamma_{m1} = 1.25$

Strength of plates in the joint

Thickness of thinner plate; $t = 20mm$

width of plate $b = 180mm$

There is no staggering = $p_{si} = 0$

Number of bolt holes in the weakest section = 3

∴ Net area at weakest section.

$$A_{n} = [b - nd_0 + 0]t$$

$$A_n = [b - nd_h + \sum_i \frac{p_{si}^2}{4g_i}]t$$

$$A_n = [b - nd_h + 0]t$$

$= [180 - 3 \times 22] \times 20 = 2280 mm^2$

Design strength of plates in the joint

$T_{dn} = 0.9 A_n f_u / \gamma_{m1}$

$= \frac{0.9 \times 2280 \times 410}{1.25}$

$= 673056 N = 673.056 KN$

Strength of Bolts:

i)- Total number of bolts = 6

Number of shear planes of thread $n_n = 1$ per bolt

Number of shear planes of shank $n_s = 0$ per bolt

∴ Total $n_n = 1 \times 6 = 6$ and total $n_s = 0$

$A_{nb} = 0.78 \times \frac{\pi}{4} d^2 = 0.78 \times \frac{\pi}{4} \times 20^2 = 245 mm^2$

There are no reduction factor i.e.

$\beta_{lj} = \beta_{lg} = \beta_{pk} = 1$

Nominal shear strength

$V_{nsb} = \frac{f_{ub}}{\sqrt{3}} (n_n A_{nb} + n_s A_{sb})$

$= \frac{400}{\sqrt{3}} (6 \times 245 \times 0) = 339482 N = 339.482 KN$

$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{339.482}{1.25} = 271.586 KN$

ii - Design strength in Bearing

Nominal strength $V_{npb} = 2.5 k_b d t f_u$

where k_b is smaller of the following

a- $\frac{e}{3d_0} = \frac{30}{3\times22} = 0.4545$

b- $\frac{p}{3d_0} - 0.25 = \frac{60}{3\times22} - 0.25 = 0.659$

c- $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.9756$

d = 1

Note- Edge distance provided is less Hence It is critical in this case

$K_b = 0.4545$

$V_{npb} = 2.5 \times 0.4545 \times 20 \times 20 \times 410 = 186364N$ per bolt

Design strength $= \frac{V_{npb}}{\gamma_{mb}} = \frac{186345}{1.25} = 149076N$

Design strength of joint $= 6 \times 149076 = 894456N$

$= 894.456 KN$

Design strength of bolts in joint $= 271.586 > T_{dn}$

strength of joint $= 271.586 KN$

Efficiency of joint

Area of solid plate $= 180 \times 20 = 3600 mm^2$

Design strength of solid plate

$= \frac{f_y}{\gamma_{m0}} \times A_g = \frac{250 \times 3600}{1.1}$

$= 818181.8N$

$= 818.818KN$

$\eta = \frac{\text{strength of joint}}{\text{strength of solid plate}} \times 100\%$

$= \frac{271.586}{818.818} \times 100 = 33.19\%$