Program : **Diploma in Architecture / Civil Engineering**	
Course Code : **5012**	Course Title: **Design of Steel and RCC Structures**
Semester : **5**	Credits: **4**
Course Category: **Program Core**	
Periods per week: **4 (L:3, T:1, P:0)**	Periods per semester: **60**

Course Objectives:

- To learn the concept of design of tension and compression members in steel structures by limit state design.
- To learn the concept of limit state design of steel beams.
- To understand design of RCC elements.
- To know the design of short RCC columns and isolated footing.

MODULE-1

Contents:

Types of sections used for Tension members. Strength of tension member by yielding of section and rupture of net cross-section. Design of axially loaded single angle and double angle tension members with welded connection.

Types of section used as compression member. Calculation of effective length, Radius of gyration and slenderness ratio, Permissible values of slenderness ratio as per IS 800, Design constant for Compressive stress.

Design of single and double angle struts with welded connections

Introduction to build up sections, lacing and battening (Meaning and purpose), Diagrams of single and double lacing and battening system. (No numerical problems).

STEEL

- Alloy of iron and carbon
- Small percentage of Manganese,Sulphur,Phosphorous,Chromium,Nickel & Copper may also present

<u>Physical properties</u>

1. Density =7850 kg/m^3
2. Modulus of elasticity =2 $x\ 10^5\ N/mm^2$
3. Poisson's ratio = 0.3
4. Modulus of rigidity = 0.769 $x\ 10^5 N/mm^2$
5. Coefficent of thermal expansion = 12 $x\ 10^{-6}$ /°C

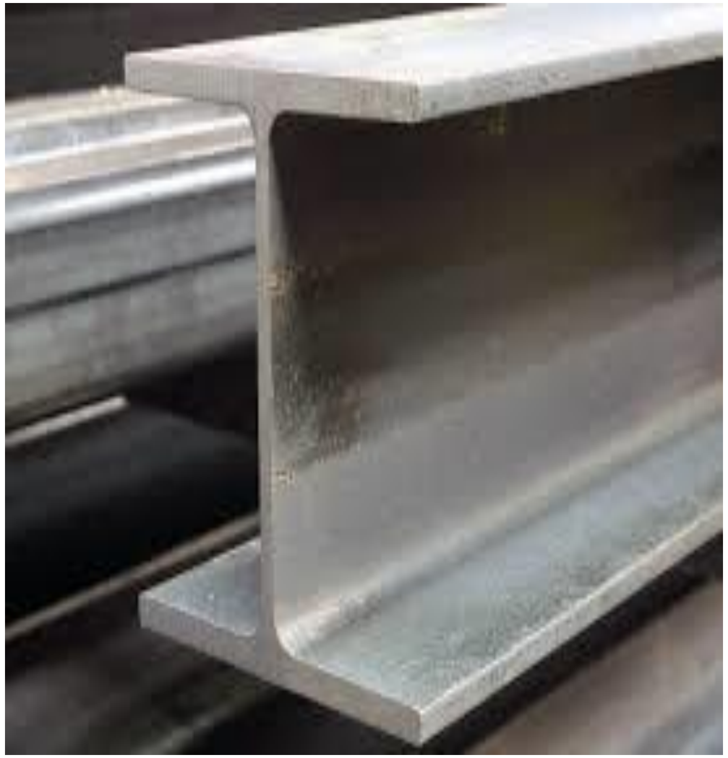
STEEL STRUCTURES

- It is the assembly of a group of steel members
- There may Tension members, Compression members, Flexural members
- Since steel needs high temp to melt it and roll in to required shape ,we cannot make desired shape and size in site.
- Therefor steel sections of standard shapes, sizes and lengths are rolled in steel mills and marketed.

STEEL SECTIONS

Various types of rolled steel sections manufactured are

1. Rolled steel I-sections
2. Rolled steel channel sections
3. Rolled steel angle sections
4. Rolled steel T-sections
5. Rolled steel bars
6. Rolled steel tubes
7. Rolled steel plates
8. Rolled steel flats
9. Rolled steel sheets and strips



I section

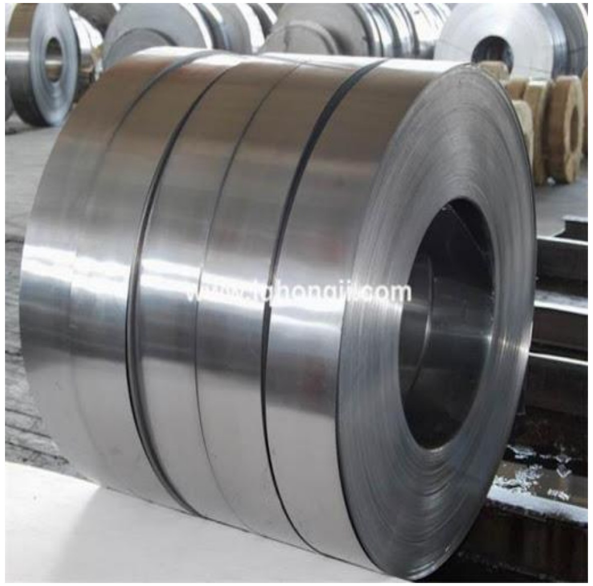
Channel section

Angle section

T section

bars

tubes



Plates

Flats

Sheets and strips

ROLLED STEEL I-SECTIONS

I-sections manufactured in India

1. Indian Standard Junior Beams (ISJB)
2. Indian Standard Light Beams (ISLB)
3. Indian Standard Medium weight Beams (ISMB)
4. Indian Standard Wide flange Beams (ISWB)
5. Indian Standard Heavy weight Beams (ISHB)

Designation

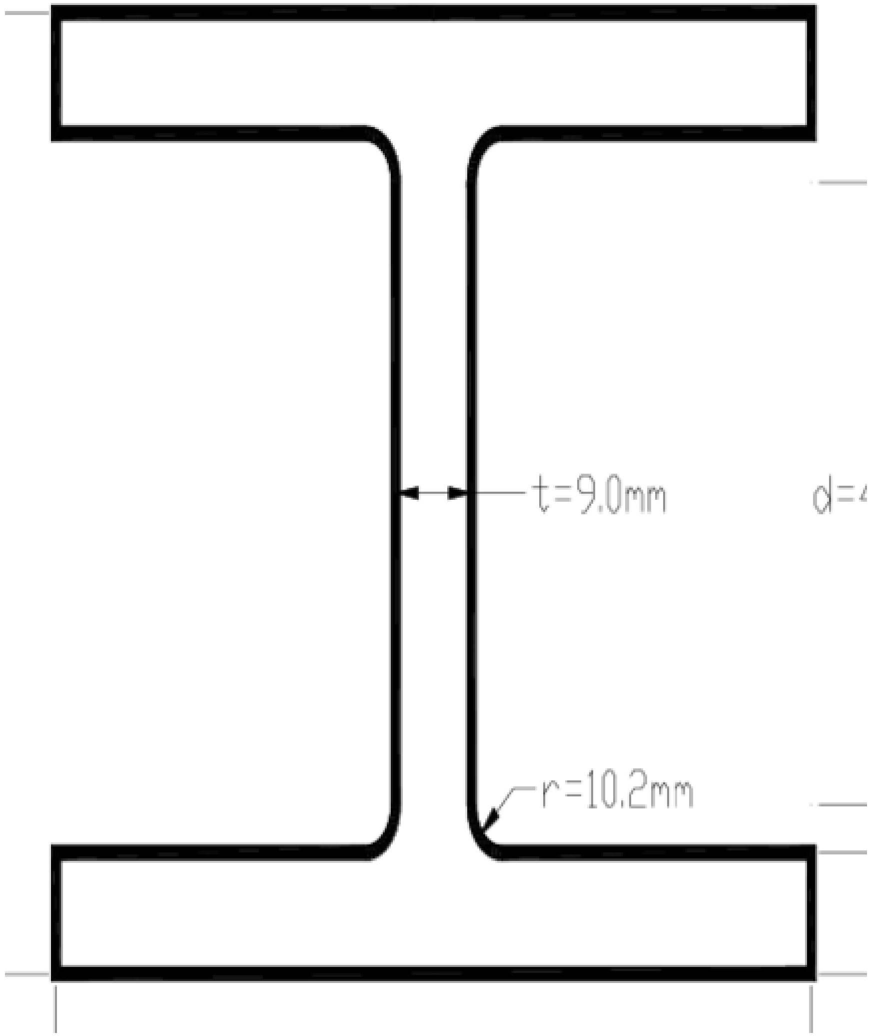
$\boxed{\text{ISMB 400 @ 61.6 kg/m}}$

Class/series

Depth in mm

Weight per meter

ROLLED STEEL I-SECTIONS



Depth

ROLLED STEEL CHANNEL SECTIONS

1. Indian Standard Junior Channel (ISJC)
2. Indian Standard Light Channel (ISLC)
3. Indian Standard Medium weight Channel (ISMC)
4. Indian Standard Special channel(ISSC)

Designation

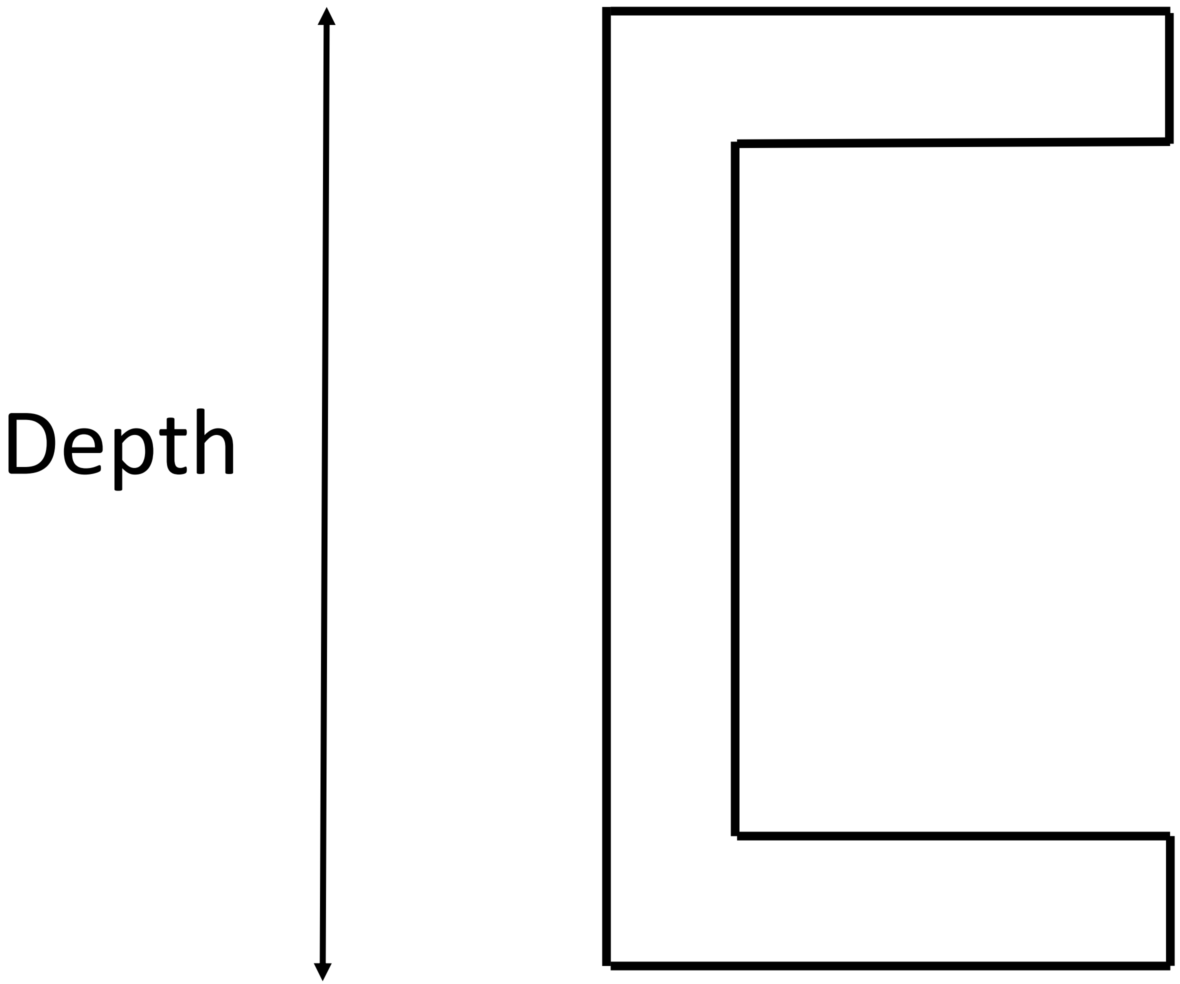
ISMC 400 @ 49.4 kg/m

Class/series

Depth in mm

Weight per meter

ROLLED STEEL CHANNEL SECTIONS



ROLLED STEEL ANGLE SECTIONS

1. Indian standard equal angles
2. Indian standard unequal angles

Designation

ISA 9090

Class/series | Length in mm | Breadth in mm

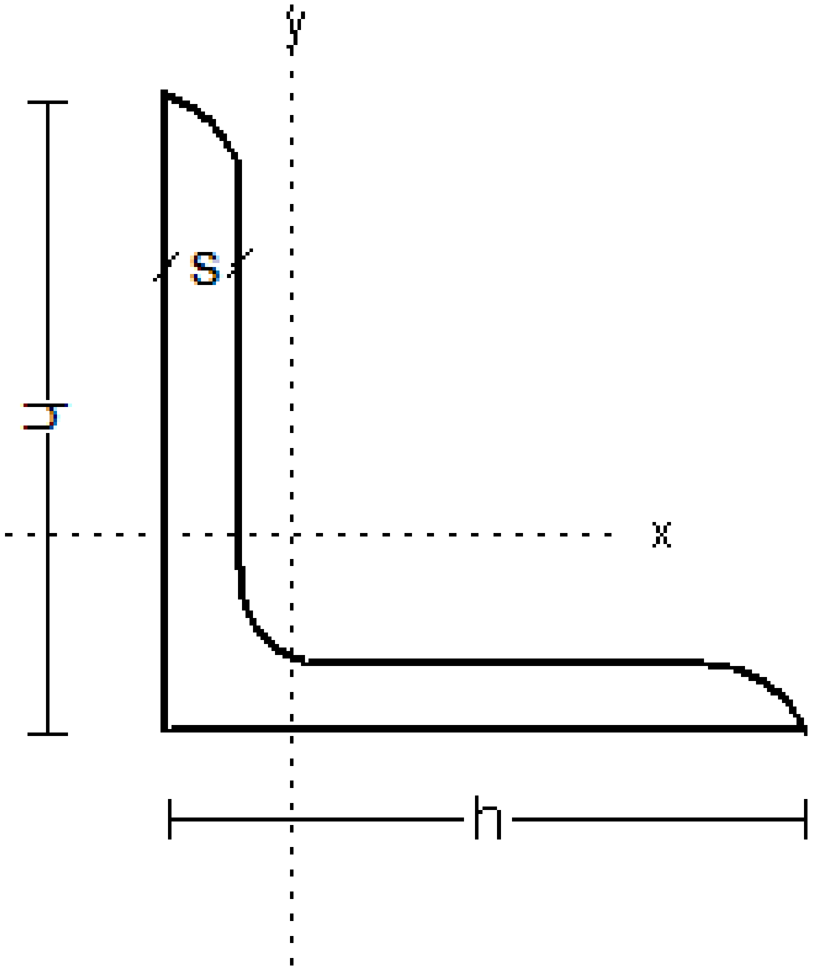
Equal angle

ISA 150115

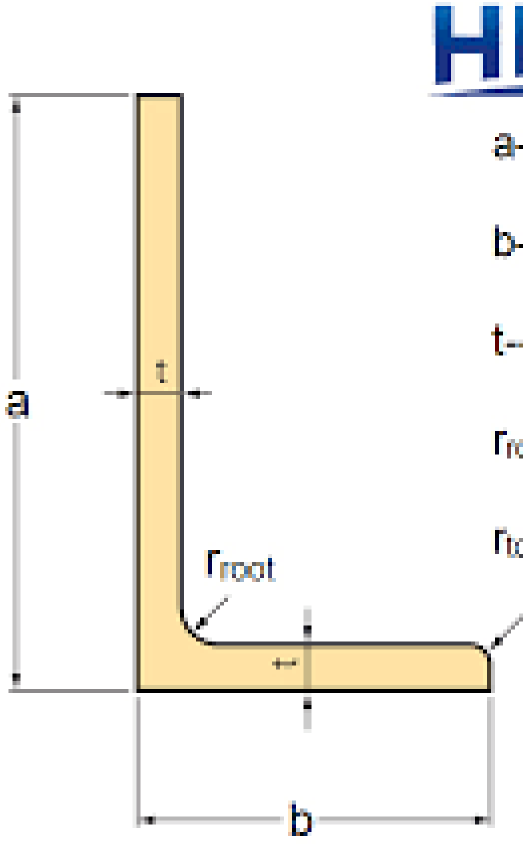
Class/series | Length in mm | Breadth in mm

Un equal angle

ROLLED STEEL ANGLE SECTIONS



Equal angle



Un equal angle

ROLLED STEEL T-SECTIONS

T-sections manufactured in India

1. Indian Standard Normal T bars (ISNT)
2. Indian Standard Heavy Flanged T bars (ISHT)
3. Indian Standard Special legged T bars (ISST)
4. Indian Standard Light T bars (ISLT)
5. Indian Standard Junior T bars(ISJT)

Designation

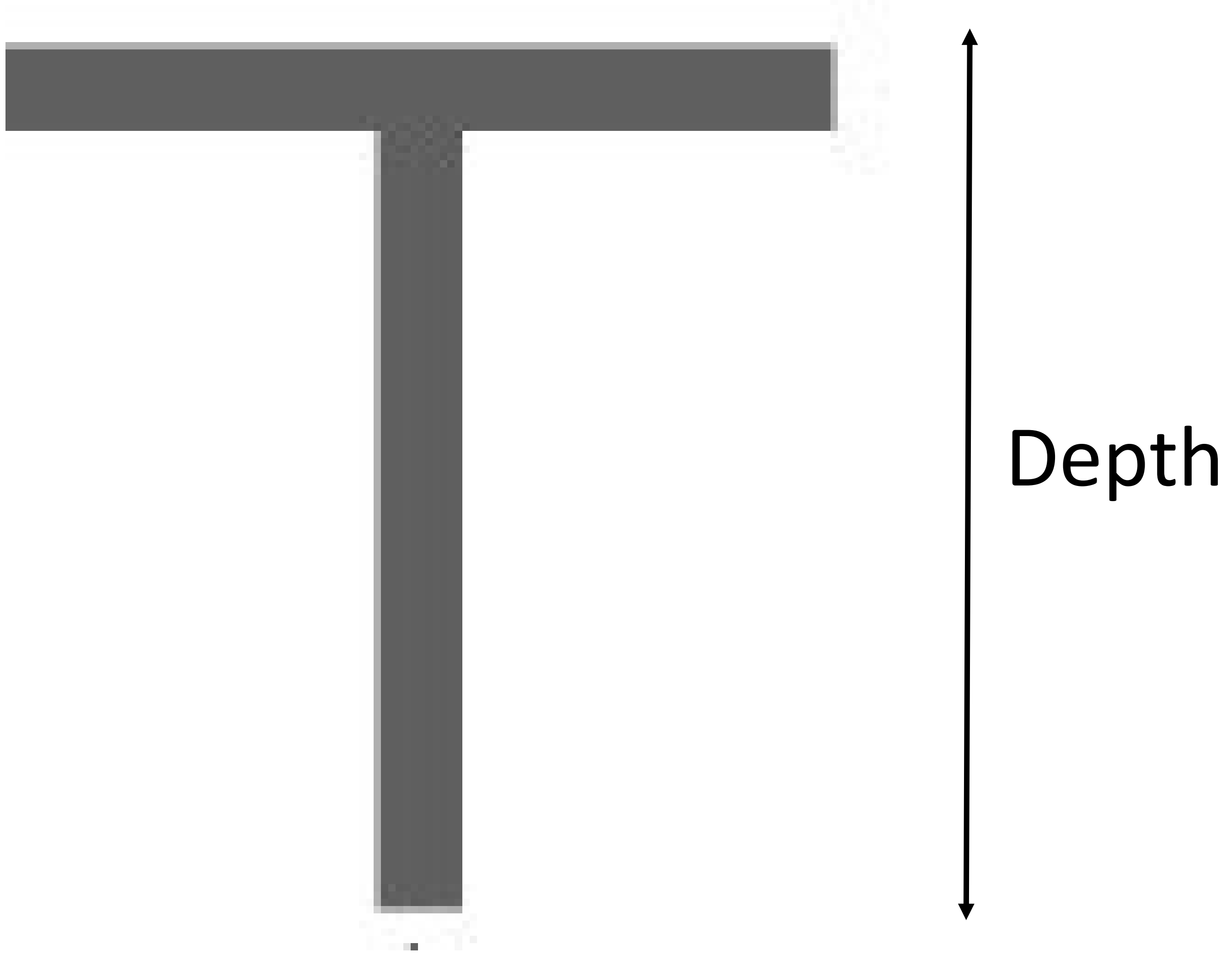
ISJT 112.5 @ 6.4Kg/m

Class/series

Depth in mm

Weight per meter

ROLLED STEEL T-SECTIONS



OTHER SECTIONS

Rolled steel plates

They are available in different length, breadth, thickness

Rolled steel strips

These are steel plates having infinite length and their thickness is less than 5mm

Rolled steel flats

These are having definite length ,limited width and having thickness greater than 5mm

STEEL OVER RCC

Advantages

1. Speedy construction
2. Dismantling and reuse is possible
3. Occupy less space than RCC
4. Modifications can be done easily
5. Self weight is less compared to RCC
6. Non porous
7. High scrap value

STEEL OVER RCC

Disadvantages

1. Subjected to corrosion, periodic maintenance is required
2. Temperature stresses will be high
3. Low fire resistance
4. Skilled labour is required for fabrication

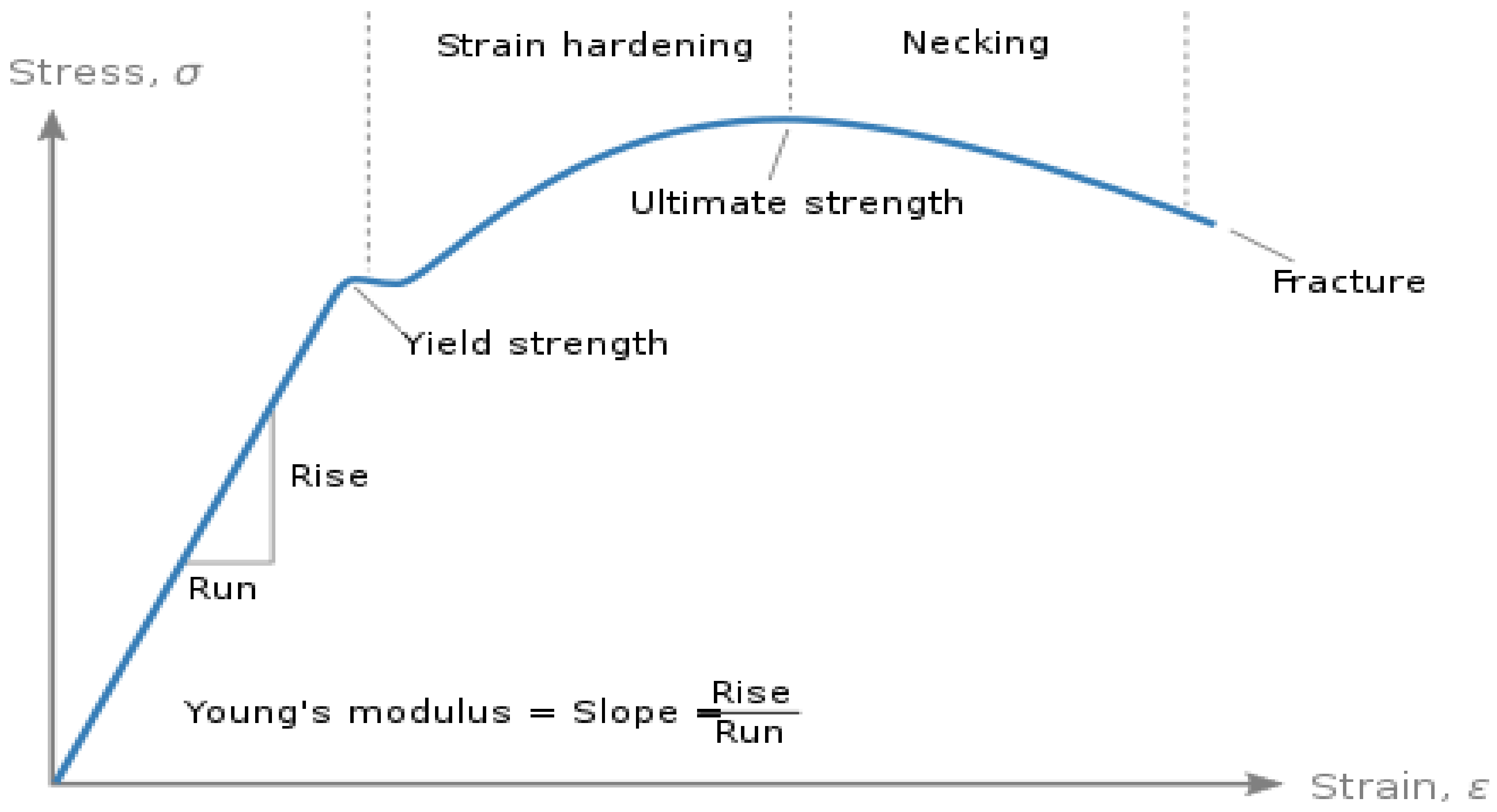
STEEL

Mechanical properties

- Yield stress (f_y) $= \frac{Load\ at\ yield\ point}{area\ of\ crosssection}$
- Ultimate stress (f_u) $= \frac{Ultimate\ load}{area\ of\ crosssection}$
- Percentage of elongation $= \frac{Final\ gauge\ length - initial\ gauge\ length}{initial\ gauge\ length} x100$

Yield stress and ultimate stresses of a steel is determined by Tensile test in UTM

STRESS-STRAIN VARIATION IN STEEL



LOADS

- Dead load – due to weight of every element of component within the structure
- Live load
- Wind load – The force exerted by the horizontal component of wind
- Earth quake load – during earthquake results from inertia forces which were created by ground accelerations
- Erection load – construction loads produced during the handling operations of heavy component erection
- Accidental load – due to impacts & collisions , explosions , fire etc

COMPRESSION MEMBERS

COMPRESSION MEMBERS

- **Commonly used sections as compression members**

  - **Single angle & Double angle sections**
  - **T sections**
  - **Single Channel and Double Channel sections**
  - **I sections**

COMPRESSION MEMBERS

- Actual length of compression members

Length of member from centre to centre of intersection with the supporting members in the plane of buckling deformation.

- Effective length

The length of an equivalent column with hinged at ends and having the same load carrying capacity as the member under consideration

- Slenderness ratio

It is the ratio of effective length to least radius of gyration

Slenderness ratio $= \dfrac{KL}{r_{min}}$

Where KL = Effective length of column

r_{min} = Least radius of gyration

$$r_{min} = \sqrt{\frac{I_{min}}{A}}$$

DESIGN STRENGTH OF COMPRESSION MEMBERS

IS 800 Page 34 to 45

Design strength of compression member should be greater than factored load

$P_d > P$

- <u>Design strength</u> (P_d)

It is the product of effective sectional area and design compressive stress

$$\boxed{P_d = A_e f_{cd}}$$

Where A_e = Effective sectional area which is equal to gross area in case of compression members

f_{cd} = Design compressive stress

DESIGN STRENGTH OF COMPRESSION MEMBERS

- Design compressive stress (f_{cd})

$$f_{cd} = \frac{\frac{f_y}{\gamma_{m0}}}{\emptyset+[\emptyset^2-\lambda^2]^{0.5}} = \frac{\chi f_y}{\gamma_{m0}}$$

Where $\emptyset = 0.5[1 + \propto (\lambda - 0.2) + \lambda^2]$

λ = Non dimensional effective slenderness ratio

$\lambda = \sqrt{\frac{f_y}{f_{cc}}}$, f_{cc} =Euler's buckling stress

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

$\propto$= Imperfection factor (Page 35,Table 7)

χ = Stress reduction factor

$$\chi = \frac{1}{\emptyset+[\emptyset^2-\lambda^2]^{0.5}}$$

Buckling class	$\propto$
a	0.21
b	0.34
c	0.49
d	0.76

Buckling class of cross sections

Cross section	Limits	Buckling about axis	Buckling class
Rolled I sections	$\frac{h}{b_f} > 1.2$ $t_f \leq 40mm$	z-z	a
		y-y	b
	$\frac{h}{b_f} > 1.2$ $40mm \leq t_f \leq 100mm$	z-z	b
		y-y	C
	$\frac{h}{b_f} \leq 1.2$ $t_f \leq 100mm$	z-z	b
		y-y	c
	$\frac{h}{b_f} \leq 1.2$ $t_f > 100mm$	z-z	d
		y-y	d

Buckling class of cross sections

Cross section	Limits	Buckling about axis	Buckling class
Welded I sections	$t_f \leq 40mm$	z-z	b
		y-y	c
	$t_f > 40mm$	z-z	c
		y-y	d
Hollow section	Hot rolled	Any	a
	Cold rolled	Any	b
Channel, angle, T and solid sections		Any	c
Built up memeber		Any	c

Effective length of columns

End condition	Effective length
Both ends fixed *(Restrained against rotation and translation at both ends)*	0.65L
Both ends hinged *(Restrained against translation and not restrained against rotation at both ends)*	1.0L
One end fixed and other end hinged *(Restrained against translation at both ends and not restrained against rotation at one end)*	0.8L
One end fixed and other end free *(Restrained against translation and rotation at one end and not restrained against translation and nor restrained against rotation at the other end)*	2.0L
Restrained against translation and rotation at one end and restrained against rotation and not restrained against translation at the other end	1.2L

Load carrying capacity of column

We know that design strength/load carrying capacity of column is

$$P_d = A_e f_{cd}$$

We can get f_{cd} directly from table 9 (a to d) (Page 40,41,42,43)

If we know yield stress ,buckling class and effective length of a column

Load carrying capacity of angle sections (Struts)

Values of ‘K’ for angle section connected by

Welding = 0.7

Q1) In a truss a strut 3m long consist of ISA 60 x 60 x 6 ,connected to gusset plate of thickness 10mm,determine the design strength of the member if it is connected by

i. Weld

Given data

Length of strut is 3m ,ISA 60 x 60 x 6

Area of cross section $A_e = 6.84\, cm^2 = 684\, mm^2$

Load carrying capacity of angle sections (Struts)

radius of gyration , $r_{xx} = r_{yy}$=18.2 mm , so $r_{min} =$ 18.2mm

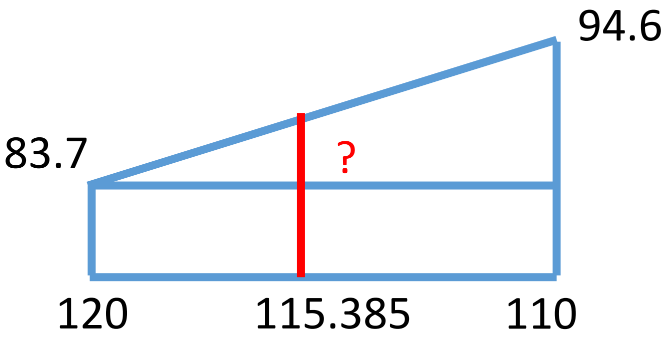
From table 10 , we know that all angle sections belongs to buckling class 'c'

<u>Design compressive stress</u> (f_{cd})

iii) Connected by weld

$\frac{KL}{r}$, For weld ,K= 0.7

$$\frac{KL}{r} = \frac{0.7\ x\ 3000}{18.2} = 115.385$$



For $\frac{KL}{r} = 115.385$ & $f_y = 250\ N/mm^2$

From table 9 (c)

We will get $f_{cd} = 88.24\ N/mm^2$

$$\frac{94.6-83.7}{110-120} = \frac{x-83.7}{115.385-120}$$

Load carrying capacity of angle sections (Struts)

Load carrying capacity wrt buckling class c (Connected by weld)

$P_d = A_e f_{cd}$

= 684 x 88.24

= 60356.16N =60.36kN

Q2) In a truss a strut 2.5m long consist of ISA 90 x 60 x 8 ,connected to gusset plate of thickness 8mm,determine the design strength of the member if it is connected by Weld

Double angle sections (Struts)

Q2) A strut 4m long consist of two angles ISA 100 x 100 x 6 .Find the load carrying capacity of the member if the angles are connected on both sides of 12mm gusset plate by welding ?

Given data

Length of strut is 4m ,ISA 100 x 100 x 6

Area of cross section $A_e = 11.67\ cm^2 = 1167\ mm^2$

Centre of gravity $C_{xx} = C_{yy} = 26.7mm$

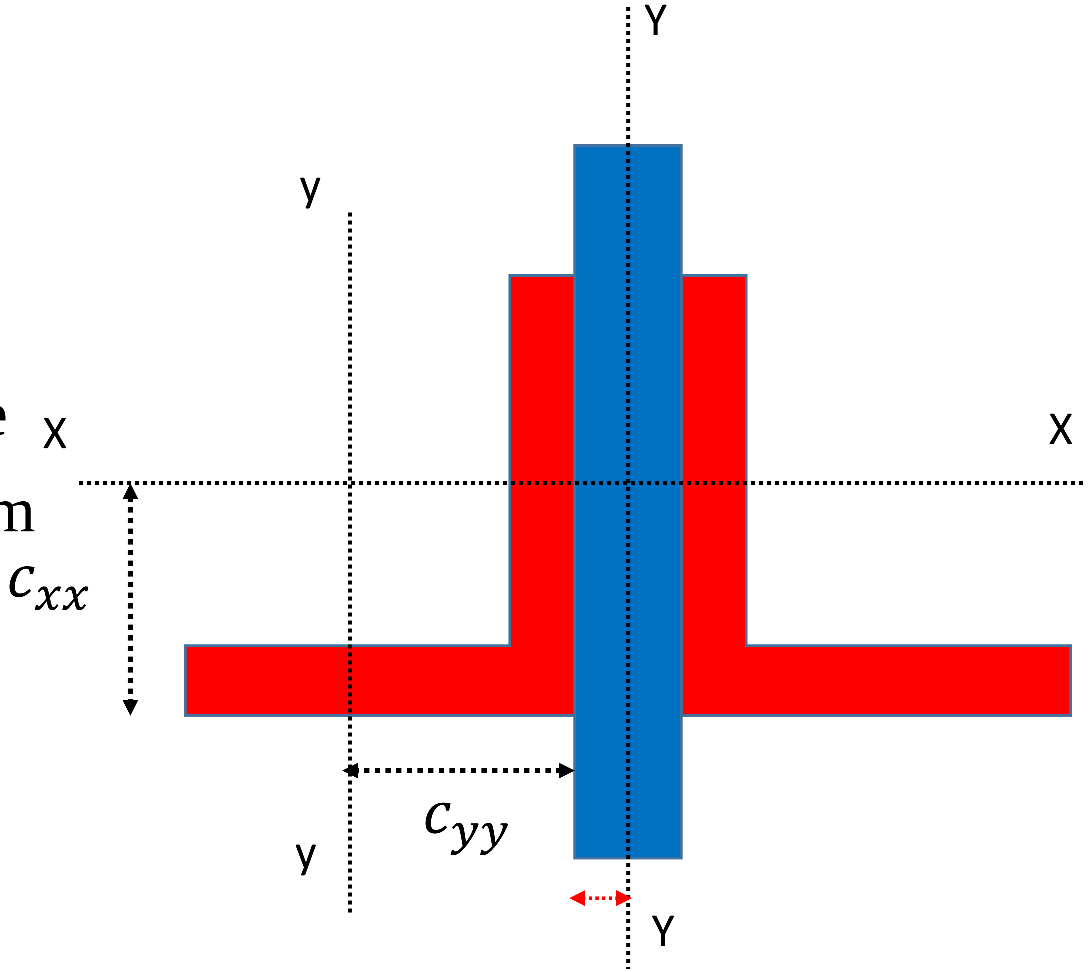
$I_{xx} = I_{yy} = 111.3\ x\ 10^4\ mm^4$

x-x axis of single will be same as that of double angle

But Y-Y axis of the double angle will be different from the y-y axis of single angle

Radius of gyration of double angle along x-x axis

$r_{xx} = 30.9mm$



Double angle sections (Struts)

Radius of gyration of double angle along Y-Y axis

$$r_{YY} = \sqrt{\frac{I_{YY}}{A}}$$

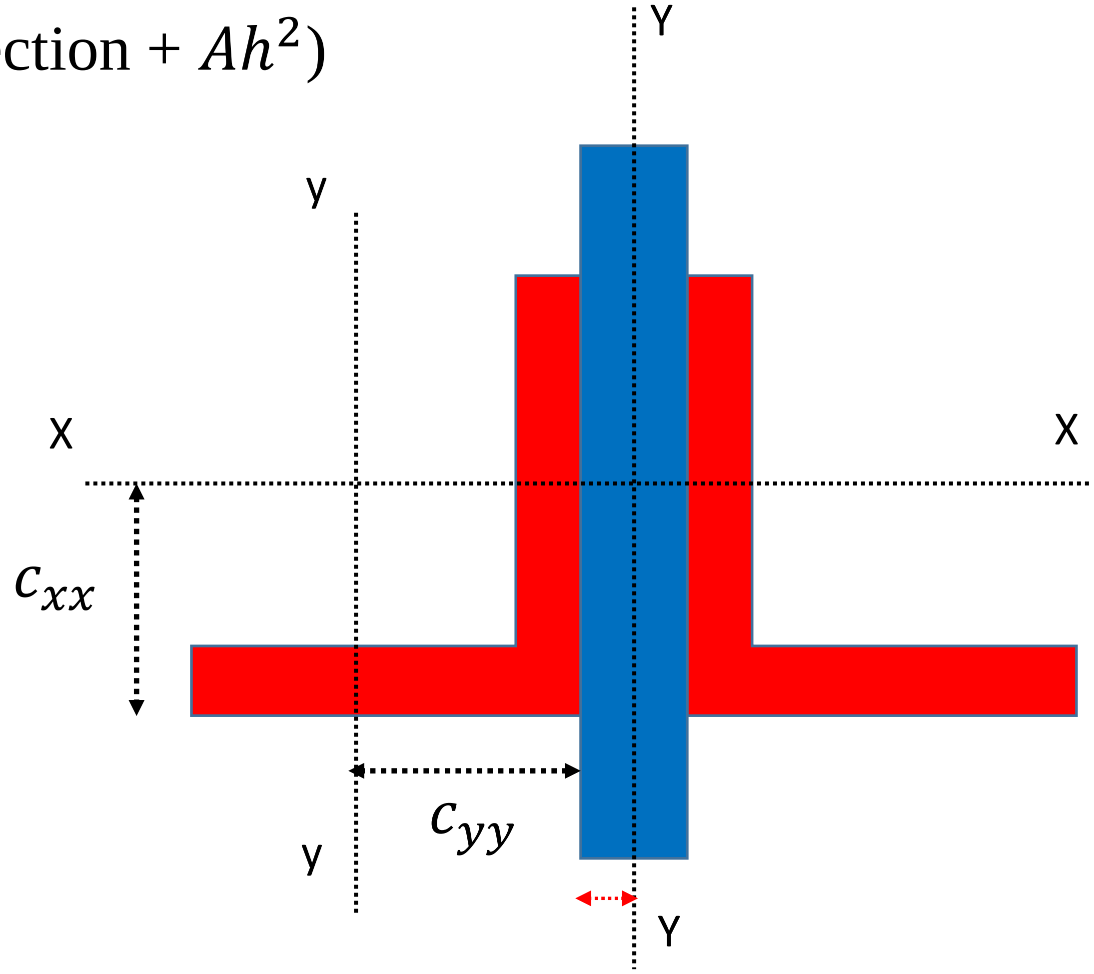
Where I_{YY} of double angle = 2 (I_{YY} of single angle section + Ah^2)

$$= 2(111.3\ x\ 10^4 + 1167\ x\ (26.7 + 6)^2\ )$$

$$= 4721722.86\ mm^4$$

$$r_{YY} = \sqrt{\frac{I_{YY}}{A}} = \sqrt{\frac{4721722.86}{2\ x\ 1167}} = 44.98mm$$

So r_{min} =30.9mm



Load carrying capacity of angle sections (Struts)

From table 10 , we know that all angle sections belongs to buckling class ‘c’

<u>Design compressive stress</u> (f_{cd})

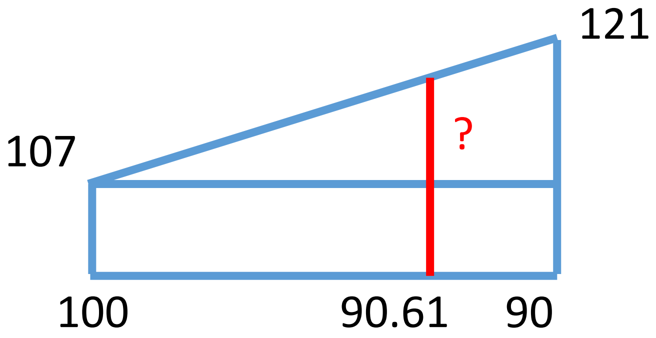
Connected by welding

$\frac{KL}{r}$, For weld K= 0.7

$$\frac{KL}{r} = \frac{0.7\ x\ 4000}{30.9} = 90.61$$

For $\frac{KL}{r} = 90.61$ & $f_y = 250\ N/mm^2$

From table 9 (c) ,by interpolating



$$\frac{121-107}{90-100} = \frac{x-107}{90.61-100}$$

We will get $f_{cd} = 120.146 N/mm^2$

Load carrying capacity wrt buckling class c

$$P_d = A_e f_{cd}$$

= 2 x 1167 x 120.146 = 280420.76N = 280.42kN

Assignment - 1

1. A single equal angle (strut) ISA 110X110X12mm of length 2.5m is connected to a gusset plate of 10mm thick by welding . determine the design strength. Take fy=300MPa
2. A strut 3m long consist of two angles ISA 75 x 75 x 8 .Find the load carrying capacity of the member if the angles are connected on both sides of 16 mm gusset plate by welding ?

Design of compression members

1) Find the factored load
2) Assume a design compressive stress (f_{cd}) to determine the area of cross section

Member	**Slenderness ratio**	f_{cd}
Rolled I sections	70 - 90	135
Angle sections (Struts)	**110-130**	**90**
For large loads		200

3) Calculate the effective sectional area required

$$A_e = \frac{P_d}{f_{cd}}$$

4) Select a section having gross area greater than the calculated area
5) Calculate slenderness ratio ($\frac{KL}{r}$)

Design of compression members

6) Find the value of f_{cd}
7) Calculate the load carrying capacity of the selected section if it is greater than factored load the design is safe ,otherwise redesign the section

Design of angle sections

Q6) Design a single angle strut connected to the gusset plate to carry a load of 140kN.The length of the strut b/w centre to centre of connection is 4m.Assume the strut to be connected to gusset plate by weld?

Given data

Working load = 140kN

Length of strut = 4m

1.) Factored load

P_d = 1.5 x 140 = 210kN

2.) Assume $f_{cd} = 90\ N/mm^2$ (Angle section)

3.) Effective sectional area required , $A_e = \frac{P_d}{f_{cd}} = \frac{210\ x\ 10^3}{90}$

= 2333.33 mm^2

4.) From steel table select ISA 110 x 110 x 12 mm

Gross area = 2502 mm^2

Design of angle sections

Slenderness ratio $\frac{KL}{r}$

K= 0.7 , L= 4000mm , $r_{min} = 33.4$mm

$$\frac{KL}{r} = \frac{0.70\ x\ 4000}{33.4} = 83.83$$

All angle section belongs to buckling class ‘c’

For $\frac{KL}{r} = 83.83$ & $f_y = 250\ N/mm^2$

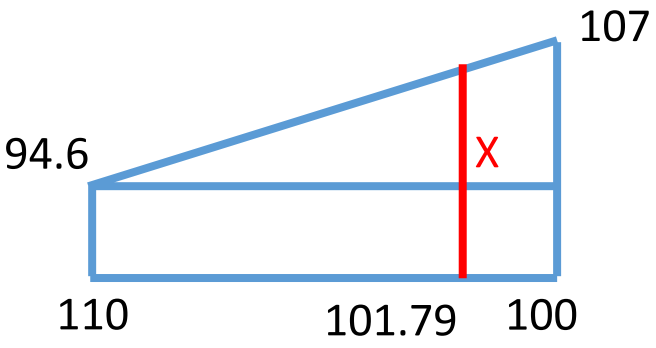
From table 9 (c) ,by interpolating

We will get $f_{cd} = ---- -\ N/mm^2$

Load carrying capacity of the angle section

$$P_d = A_e f_{cd}$$

= 2502 x 104.78 = 262159.56N = 262.16kN



$$\frac{107-94.6}{100-110} = \frac{x-94.6}{101.79-110}$$

Design of angle sections

Load carrying capacity = 262.15kN > Factored load 210kN

Hence the design is safe and provide ISA 110 x 110 x 12 mm

Design of double angle sections

Q9) Design a double angle discontinuous strut to carry axial load of 300kN,The length of the member is 3m.The angles are connected to the gusset plate of 10mm thick using weld?

Given data

Working load = 300kN

Length of strut = 3m

1.) Factored load

P_d = 1.5 x 300 = 450kN

Load on single angle $=\frac{450}{2} = 225\ kN$

2.) Assume $f_{cd} = 90\ N/mm^2$ (Angle section)

3.) Effective sectional area required , $A_e = \frac{P_d}{f_{cd}} = \frac{225\ x\ 10^3}{90} = 2500\ mm^2$

4.) From steel table select ISA 130 x 130 x 10 mm

Gross area = 2506 mm^2

Design of double angle sections

Slenderness ratio $\frac{KL}{r}$

K= 0.7 , L= 3000mm , $r_{min} = 40.1$mm

$$\frac{KL}{r} = \frac{0.7\ x\ 3000}{40.1} = 52.37$$

All angle section belongs to buckling class ‘c’

For $\frac{KL}{r} = 52.37$ & $f_y = 250\ N/mm^2$

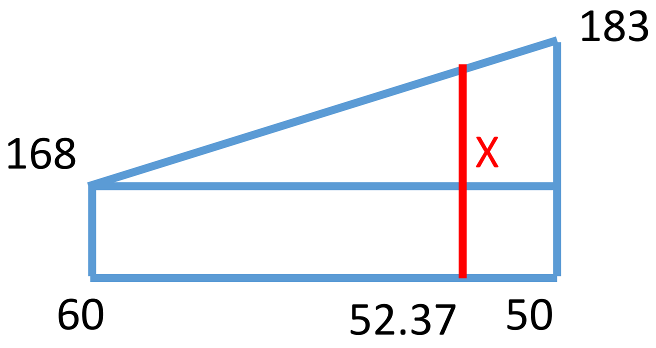
From table 9 (c) ,by interpolating

We will get $f_{cd} = 179.445\ N/mm^2$

Load carrying capacity of the angle section

$$P_d = A_e f_{cd}$$

= 2506 x 179.445 = 449689.17N = 449.69kN



$$\frac{183-168}{50-60} = \frac{x-168}{52.37-60}$$

Design of double angle sections

Load carrying capacity = 449.69kN > Factored load 225kN

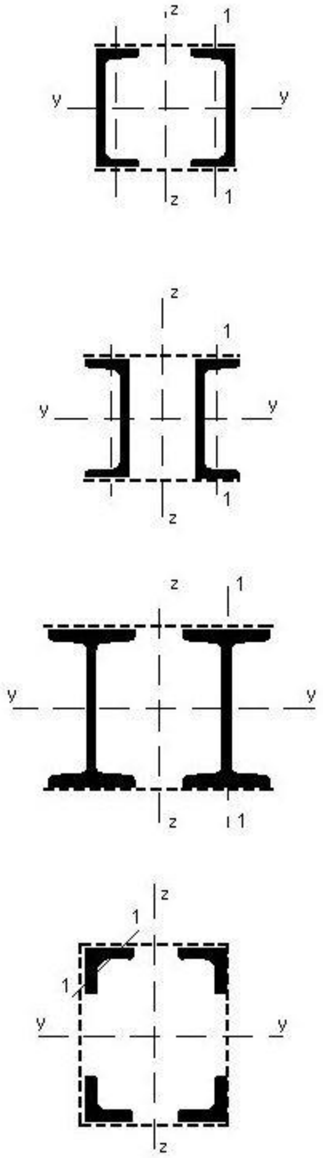
Hence the design is safe and provide **ISA 130 x 130 x 10 mm**

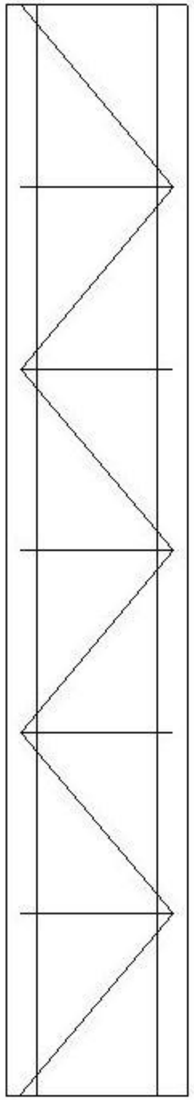
Assignment - 1

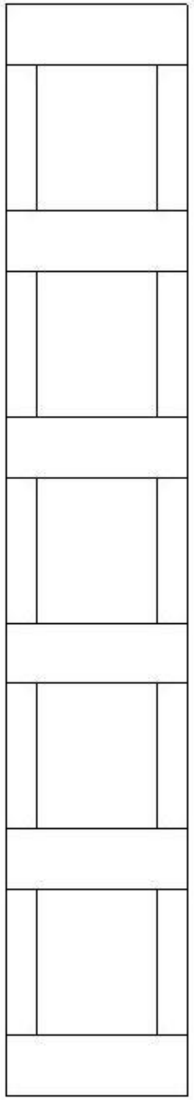
3. Design a single angle strut welded to a gusset plate carrying a factored load of 180kN. The length of member is 3m, fy=250N/mm2

4. Design a double angle discontinuous strut to carry axial load of 400kN,The length of the member is 3.5m.The angles are connected to the gusset plate of 12mm thick using weld?

Lacing & Batten

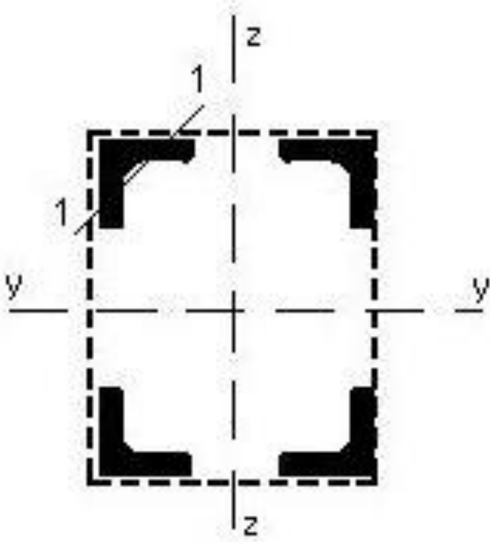






Lacing & Batten

- To achieve maximum value of radius of gyration without increasing the area of the section a number of elements are placed away from the principal axis using suitable lateral system
- They are provided to hold the different components of a built up column and to increase its load carrying capacity
- Load carrying capacity is increased by increasing radius of gyration (Thus by reducing slenderness ratio)
- Commonly used lateral systems are lacing and battens

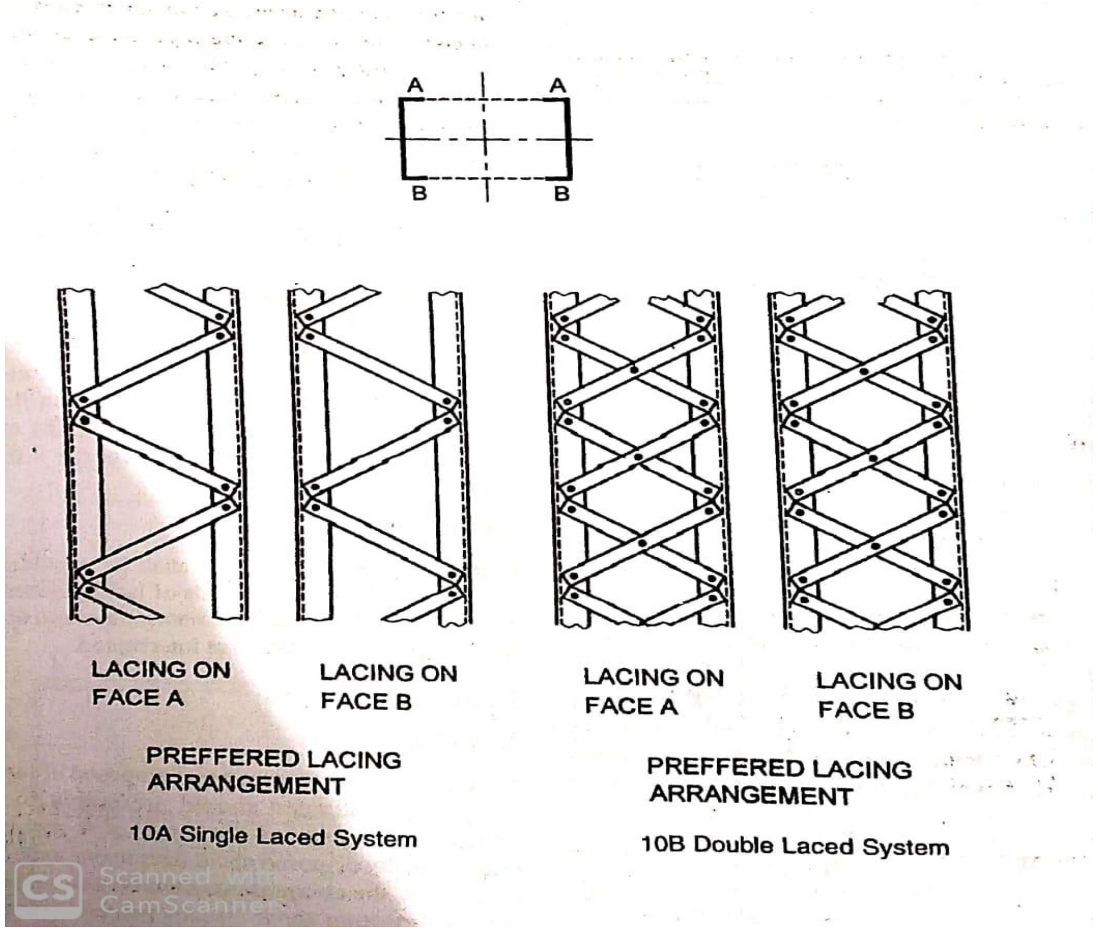


Lacing

- **Lacing** consists of connecting the components of the column by a system of generally flat plates, angles or channels
- Mainly there are two types of lacing arrangement

i) Single lacing

ii)Double lacing



IS code provisions for lacing IS 800 Page 48 to 50

- Lacing system shall be uniform throughout the length of column
- In single laced system on opposite faces of the components being laced together shall preferably be in the same direction so that one is the shadow of the other, instead of being mutually opposed in direction
- The effective slenderness ratio shall be taken as 1.05 times the actual slenderness ratio
- In bolted/riveted connection minimum width of lacing bars shall be three times the nominal diameter of the end bolt/rivet
- The thickness of flat lacing bar shall not be less than

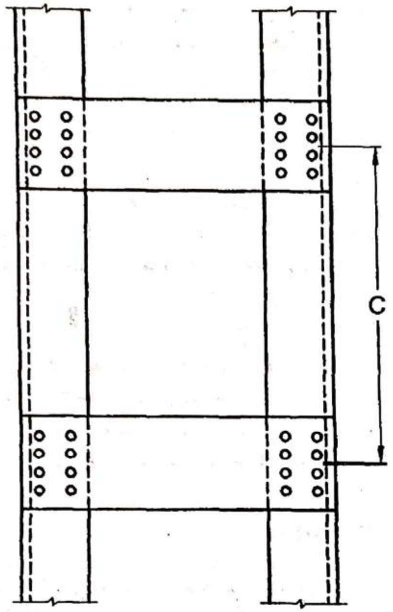
  $\frac{1}{40}$ of effective length (for single lacing)

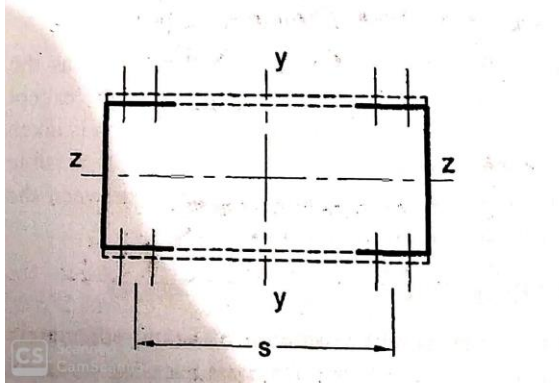
  $\frac{1}{60}$ of effective length (for double lacing)
- Lacing bar shall be inclined at an angle not less than 40^o nor more than 70^o to the axis of the built up member

Battens

- **Battens** are plates or any other rolled section used to connect the main components of compression members
- Based on the position of the battened plate there are end battens&

  intermediate battens





IS code provisions for battens IS 800 Page 50 to 52

- Batten plates should be provided symmetrically
- Battens shall be placed opposite to each other
- The number of battens should be such that the member is divided in to not less than 3 bays
- The effective slenderness ratio shall be taken as 1.1 times the actual slenderness ratio
- The effective depth of flat batten bar shall not be less than

  Distance between the centroids of the main member (for end batten)

  $\frac{3}{4}$ Distance between the centroids of the main member (for intermediate batten)
- The thickness of batten shall not be less than $\frac{1}{50}\ th$ of the distance between the innermost connecting lines

TENSION MEMBERS

TENSION MEMBERS

- Linear members in which axial forces act so as to elongate (Stretch) the member
- They carries loads more efficiently since the entire cross section is subjected to uniform stress
- They do not fail by buckling
- Examples -: Ties of roof trusses, suspenders of cable stayed and suspension bridges..etc
- They can be in the form of

1) Open sections -: Angle,channel,I section

2) Compound and built-up sections -:Double angle, double channel

3) Closed section -:Circular, square, rectangular, hollow sections

TENSION MEMBERS

Gross area & Net area

- Gross area -: The total area of cross section without deducting the area of the holes in it is called gross area of the members
- Net sectional area /net area -:The area of cross section of the member after deducting the area of holes

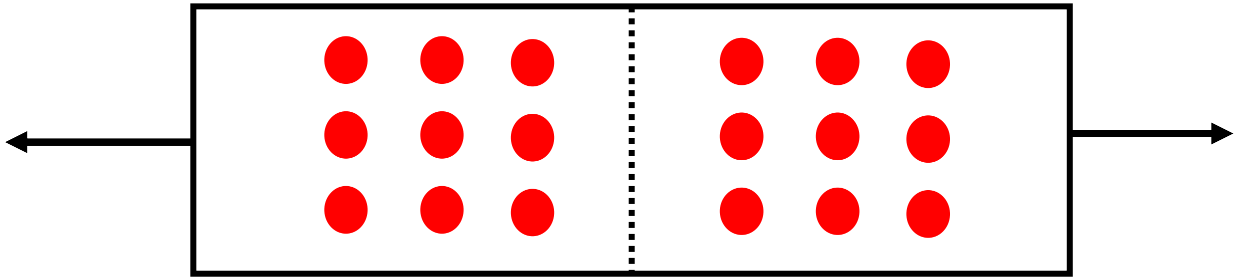
Net sectional area

For chain bolting

$A_n = A_g - sectional\ area\ of\ holes$

$= bt\text{-}n(d_h t)$

$= (b\text{-}nd_h)t$



Where A_g=gross area, A_n = net sectional area ,b =width of plate

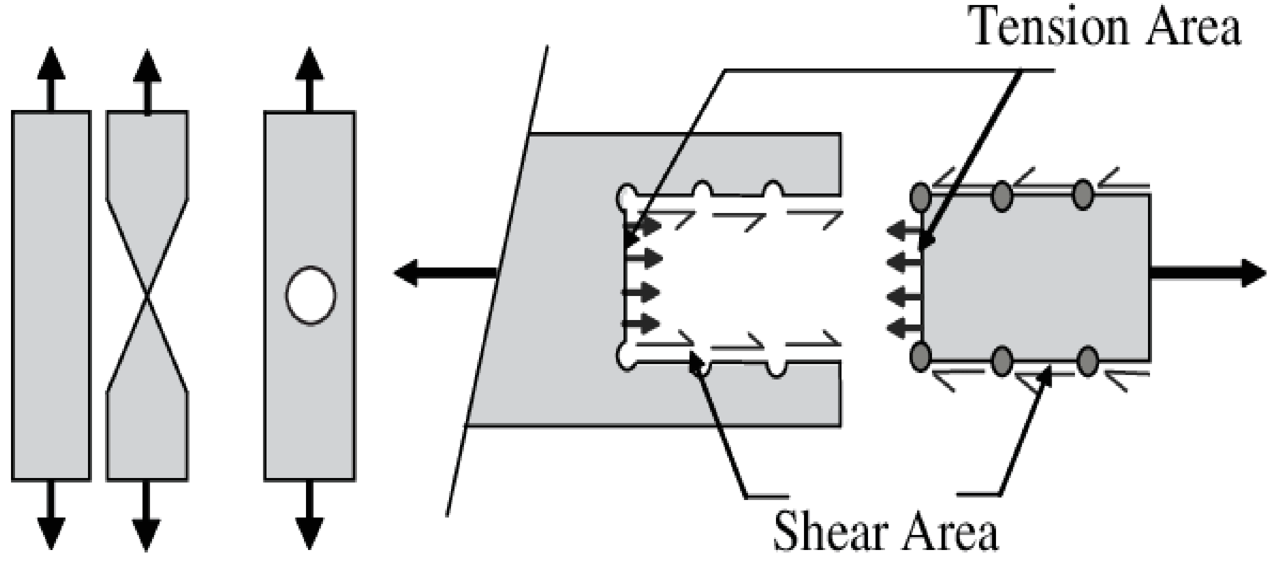
n=number of bolts , d_h =dia of bolt hole, t= thickness of plate

FAILURES IN TENSION MEMBERS

a) **Gross section yielding-**:Considerable deformation of the member in longitudinal direction may take place before it fracture, making the structure unserviceable

b) **Net section rupture -**:The fracture of the member when the net cross section (A section with bolt/rivet holes)of the member reaches the ultimate stress

c) **Block shear failure -**:A segment or block of material at end of member shears out



(a) (b) (c)

DESIGN STRENGTH OF TENSION MEMBERS

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a) **Design strength due to yielding of gross section**
b) **Design strength due to rupture of critical section**
c) **Design strength due to block shear**

DESIGN STRENGTH OF TENSION MEMBERS

IS 800 ,Page 32 to 34

a) Design strength due to yielding of gross section

- Steel can resist tension beyond yield point
- But a member loaded beyond the yield point will elongate excessively before failure
- This excessive elongation causes the member unserviceable and may even cause failure
- So load corresponding to yielding of gross section should be accounted while designing

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

Strength due to gross section yielding

Q1.Calculate the design strength of tension member due to yielding of gross section for ISA 100 x 65 x 10 ,yield stress is 250MPa?

Ans-:

Given data

f_y = 250 N/mm^2

For ISA 100 x 65 x 10 from steel table (Page No. 14)

A_g= 15.51 cm^2 = 1551 mm^2

We have $$T_{dg} = A_g \frac{f_y}{\gamma_{mo}}$$

$$= \frac{1551 \ x \ 250}{1.1}$$ =352.5kN

DESIGN STRENGTH OF TENSION MEMBERS

IS 800 ,Page 32 to 34

a) Design strength due to rupture of critical section

- Plates with bolt holes will have cross sectional area less than that of gross area
- So these sections will develop higher stresses, even before elongation of the member takes place
- So the member can fail by fracture at the net section through the holes
- So the fracture strength of the net section through the bolt holes at the member end is considered while designing

$$\boxed{T_{dn} = \frac{0.9 A_n f_u}{\gamma_{ml}}}$$

Where , γ_{ml} = Partial safety factor for failure at ultimate stresses

$$A_n = \left[b - n d_h + \sum_{i}^{n} \frac{{p_{si}}^2}{4 g_i}\right] t$$

DESIGN STRENGTH OF TENSION MEMBERS

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For single angles

$$T_{dn} = \frac{0.9A_{nc}f_u}{\gamma_{ml}} + \frac{\beta A_{go}f_y}{\gamma_{m0}}$$

Where β =1.4-0.076$\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right) \leq 0.9\left(\frac{f_u\gamma_{m0}}{f_y\gamma_{ml}}\right)$

≥ 0.7

A_{nc} = Net area of connected leg

A_{go} = Gross area of outstanding leg

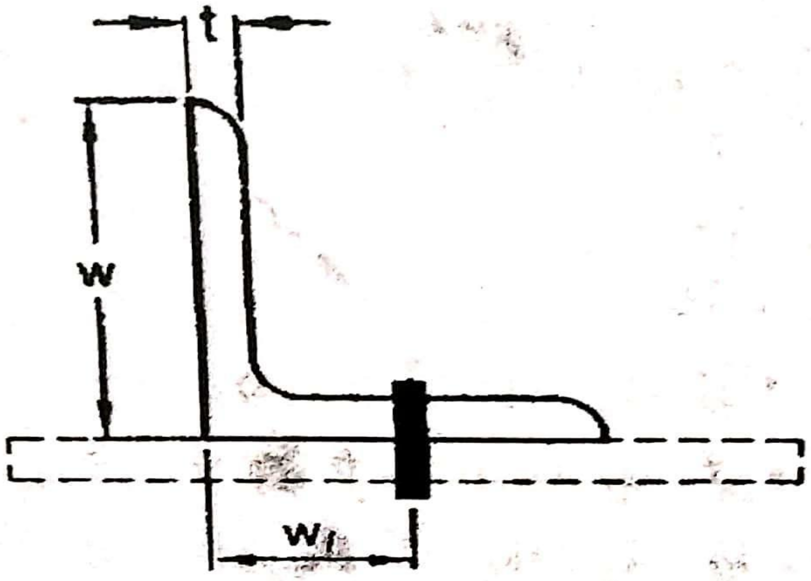
w = Outstanding leg width

b_s = Shear lag width

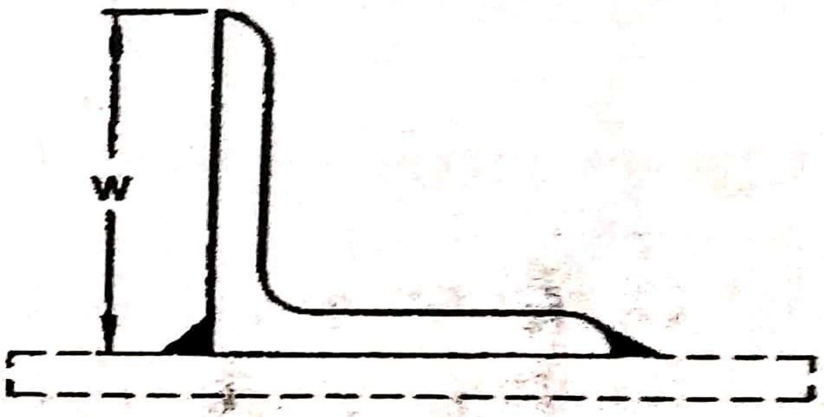
L_c = Length of the end connection (Distance between outermost bolts)

IS 800 ,Page 32 to 34

Shear lag width



$b_s = w + w_l - t$



$b_s = w$

DESIGN STRENGTH OF TENSION MEMBERS

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c) Design strength due to block shear

- Tearing out of a segment or block of material at the end of a member
- Block shear strength of connection shall be taken as the smaller of

$$T_{db} = \left[\frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{ml}}\right]$$

Or

$$T_{db} = \left[\frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{ml}} + \frac{A_{tg} f_y}{\gamma_{m0}}\right]$$

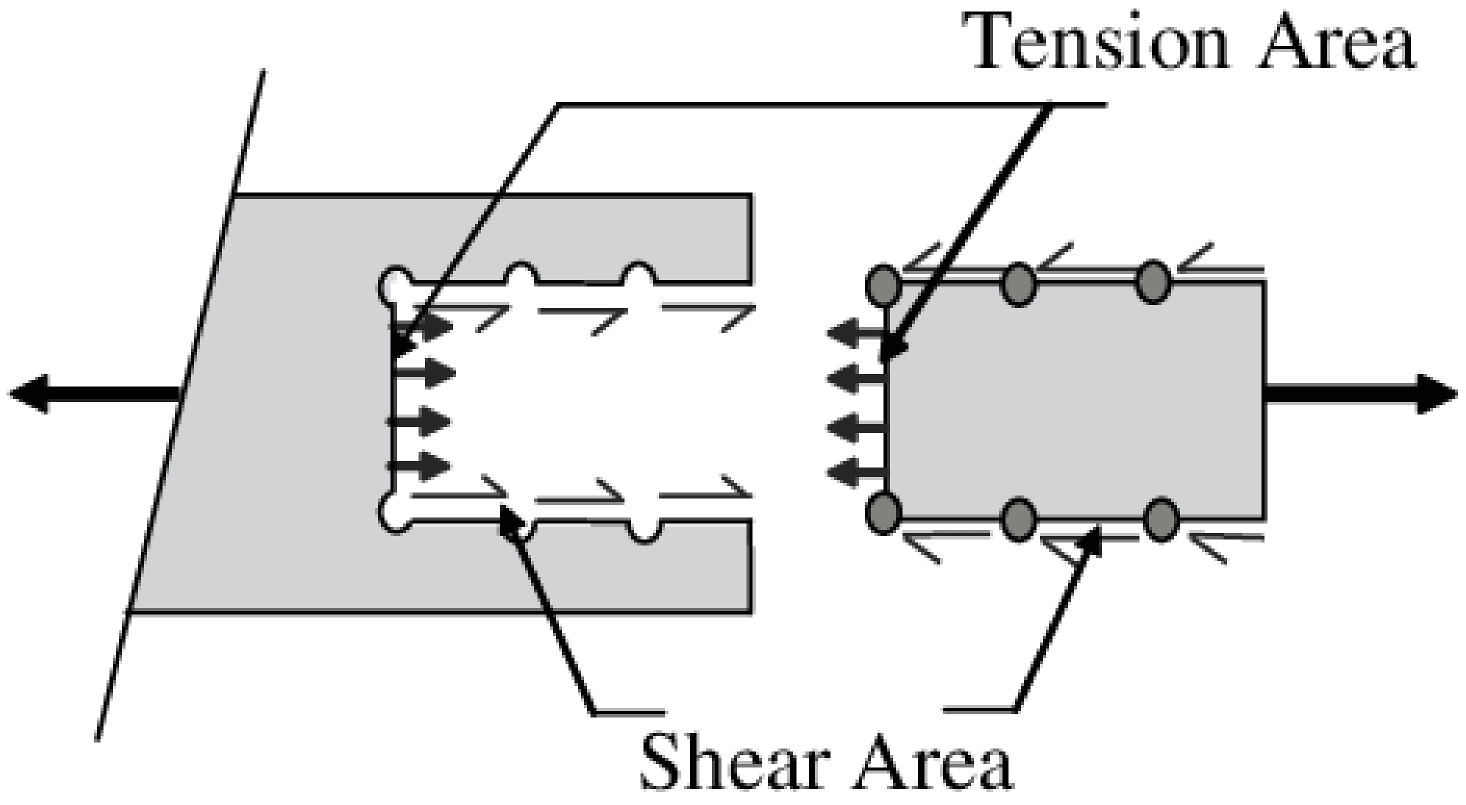
A_{vg} = Gross area in shear

A_{vn} = Net area in shear

A_{tg} = Gross area in tension

A_{tn} = Net area in tension

DESIGN STRENGTH OF TENSION MEMBERS



(c)

DESIGN STRENGTH OF TENSION MEMBERS

Q .A single angle ISA 200x100x10 mm is connected to a gusset plate of 12mm thick by fillet weld of 6mm size .Determine the design strength with f_y= 300MPa, f_u= 440MPa, length of weld =300mm ?

Ans –:

Given data

ISA 200x100x10

$A_g = 29.03\ cm^2 = 2903\ mm^2$

L =length of connected leg = 200mm

b = length of outstanding leg = 100 mm

Size of weld S= 6mm

Length of weld L_w = 300mm

DESIGN STRENGTH OF TENSION MEMBERS

1.Design strength due to yield of gross section

$$T_{dg} = A_g \frac{f_y}{\gamma_{mo}} = 2903\ X \frac{300}{1.1} \quad = 791.73\text{kN}$$

2.Design strength due to net section rupture

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{ml}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$$

$$A_{nc} = \left(L - \frac{t}{2}\right) t = \left(200 - \frac{10}{2}\right) 10 \ = 1950\ mm^2$$

$$\beta = 1.4\text{-}0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right)$$

w =100mm ,t =10mm ,

$b_s = W$ =100mm

L_c =length of weld=300mm

$$\beta = 1.4\text{-}0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right) = 1.4\text{-}0.076\left(\frac{100}{10}\right)\left(\frac{300}{440}\right)\left(\frac{100}{300}\right) = 1.227$$

DESIGN STRENGTH OF TENSION MEMBERS

$$\beta \leq 0.9\left(\frac{f_u \gamma_{mO}}{f_y \gamma_{ml}}\right) = 0.9\left(\frac{440 * 1.1}{300 * 1.25}\right) = 1.1616$$

$$\geq 0.7$$

So β = 1.162

$$A_{go} = \left[b - \frac{t}{2}\right] t = \left[100 - \frac{10}{2}\right] 10 = 950\, mm^2$$

Design strength due to net section rupture is

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{ml}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$$

$$= \frac{0.9 * 1950 * 440}{1.25} + \frac{1.162 * 950 * 300}{1.1} = 918.82 kN$$

DESIGN STRENGTH OF TENSION MEMBERS

3.Design strength due to block shear

$$T_{db1} = \left[\frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{ml}}\right]$$

Or

$$T_{db2} = \left[\frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{ml}} + \frac{A_{tg} f_y}{\gamma_{m0}}\right]$$

$A_{vg} = A_{vn} = L_w x\ 2S$

= 300 x 2 x 6

= 3600 mm^2

$A_{tg} = A_{tn}$ =Length of connected leg x 2S = 200 x2 x 6

= 2400 mm^2

DESIGN STRENGTH OF TENSION MEMBERS

$$T_{db1} = \left[\frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{ml}}\right]$$

$$= \left[\frac{3600\ x\ 300}{\sqrt{3} * 1.1} + \frac{.9 * 2400 * 440}{1.25}\right] = 1327.17 kN$$

$$T_{db2} = \left[\frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{ml}} + \frac{A_{tg} f_y}{\gamma_{m0}}\right]$$

$$= \left[\frac{0.9 * 3600 * 440}{\sqrt{3} * 1.25} + \frac{2400 * 300}{1.1}\right] = 1313.00 kN$$

Design strength due to block shear = 1313.00kN

DESIGN STRENGTH OF TENSION MEMBERS

Design strength due to gross section yielding =791.73 kN

Design strength due to net section rupture =918.82 kN

Design strength due to block shear = 1313.00 kN

Design tensile strength of the member = 791.73kN

DESIGN OF TENSION MEMBERS

Procedure

1. Determination of factored load

Factored load = 1.5 x working load

2. Identifying the required section

Area required = $\dfrac{Factored\ load}{\frac{f_y}{\gamma_{mo}}}$

Provide an area of section which is more than required area (Roughly 25 to 40%)

3. Determine the number of bolts or the welding required and arrange
4. Check for the of the tensile strength of member

   i) Gross section yielding

   ii) Net section rupture

   iii) Block shear failure

Lower of the 3 should be greater than the factored load

DESIGN OF TENSION MEMBERS

Q-: Design a single angle tension member connected by welding on a 12mm thick gusset plate to carry an axial tension of 150kN, ?

Ans-:

Given data

Thickness of gusset plate =12mm

Axial tension to be carried = 300kN

1.Determination of factored load

Factored load = 1.5 x 150 = 225 kN

2.Identifying the required section

Area required = $\dfrac{Factored\ load}{\frac{fy}{\gamma mo}}$

$= \dfrac{225\ x\ 10^3}{\frac{250}{1.1}} = 990mm^2$

We have to provide an angle section having gross area greater than $990mm^2$

So provide an angle section ISA 65 x 65 x10 mm having gross area = $1200mm^2$

3. Design of weld

Weld will be designed to transmit a force equal to 225kN

Minimum size of weld = 5 mm

Maximum size of weld = 10-1.5 = 8.5mm

So assume size of weld S = 6mm

Throat thickness t = .7 x 6 = 4.2mm

Design strength of weld $= \frac{f_u}{\sqrt{3}\,\gamma_{mw}} \times L_w \times t$

$$= \frac{410}{\sqrt{3} \times 1.5} \times L_w \times 4.2$$

$$= 662.8 \times L_w$$

Equating design strength of weld to the load coming on the weld

$$662.8\, L_w = 225 \times 10^3$$

$$L_w = \frac{225 \times 10^3}{662.8} = 339.5 \text{ mm}$$

So Provide weld of size 6mm and length 339.5 mm

DESIGN STRENGTH OF TENSION MEMBERS

4.

a)Design strength due to yield of gross section

$$T_{dg} = A_g \frac{f_y}{\gamma_{mo}} = 1200\ X \frac{250}{1.1} = 270.27\text{kN} > 225\text{kN}$$

b)Design strength due to net section rupture

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{ml}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$$

$$A_{nc} = \left(L - \frac{t}{2}\right) t = \left(65 - \frac{10}{2}\right) 10 = 600\ mm^2$$

$$\beta = 1.4 - 0.076 \left(\frac{w}{t}\right) \left(\frac{f_y}{f_u}\right) \left(\frac{b_s}{L_c}\right)$$

w =65mm ,t =10mm ,

$$b_s = w = 65mm$$

DESIGN STRENGTH OF TENSION MEMBERS

$$L_c = length\ of\ weld = 339.5\ mm$$

$$\beta = 1.4\text{-}0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right) = 1.4\text{-}0.076\left(\frac{65}{10}\right)\left(\frac{250}{410}\right)\left(\frac{65}{339.5}\right) = 1.34$$

$$\beta \leq 0.9\left(\frac{f_u \gamma_{mO}}{f_y \gamma_{ml}}\right) = 0.9\left(\frac{410 * 1.1}{250 * 1.25}\right) = 1.298$$

$$\geq\ 0.7$$

So β = 1.98

$$A_{go} = \left[b - \frac{t}{2}\right] t = \left[65 - \frac{10}{2}\right] 10 = 600\ mm^2$$

Design strength due to net section rupture is

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{ml}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$$

$$= \frac{0.9 * 600 * 410}{1.25} + \frac{1.298 * 600 * 250}{1.1} = 354.12 kN > 225\text{kN}$$

DESIGN STRENGTH OF TENSION MEMBERS

c).Design strength due to block shear

$$T_{db1} = \left[\frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{ml}}\right]$$

Or

$$T_{db2} = \left[\frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{ml}} + \frac{A_{tg} f_y}{\gamma_{m0}}\right]$$

$A_{vg} = A_{vn} = L_w x\ 2S$

= 339.5 x 2 x 6

= 4074 mm^2

$A_{tg} = A_{tn}$ =Length of connected leg x 2S = 65 x2 x 6

= 780 mm^2

DESIGN STRENGTH OF TENSION MEMBERS

$$T_{db1} = \left[\frac{A_{vg}f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9A_{tn}f_u}{\gamma_{ml}}\right]$$

$$= \left[\frac{4074\ x\ 250}{\sqrt{3}*1.1} + \frac{.9*780*410}{1.25}\right] = 283.71kN$$

$$T_{db2} = \left[\frac{0.9A_{vn}f_u}{\sqrt{3}\gamma_{ml}} + \frac{A_{tg}f_y}{\gamma_{m0}}\right]$$

$$= \left[\frac{0.9*4074*410}{\sqrt{3}*1.25} + \frac{780*250}{1.1}\right] = 871.62kN$$

Design strength due to block shear = 283.71kN > 225kN

Hence design is safe