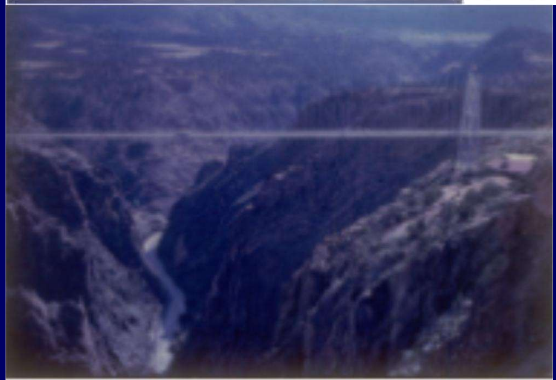
DESIGN OF TENSION MEMBERS







INTRODUCTION

Characteristics

- Members Experience
  - Axial force
  - Stretching
  - Uniform stress over the cross section
- Very Efficient Member
  - Strength governed by the material strength
  - Bolt holes affect the strength

INTRODUCTION

Applications:

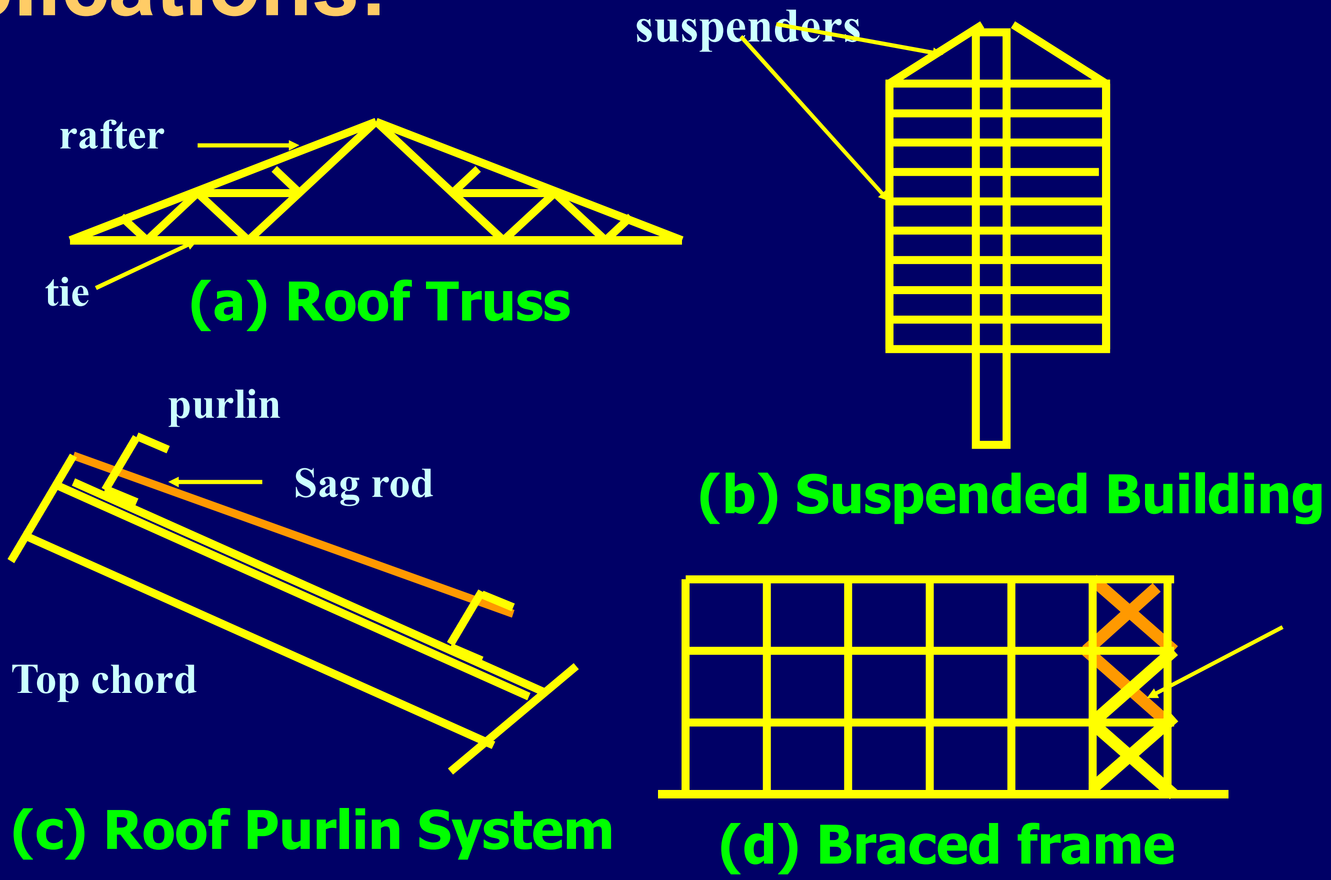
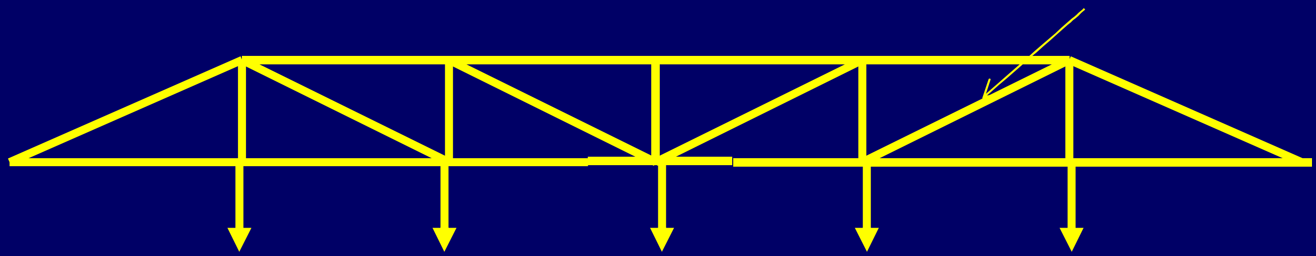
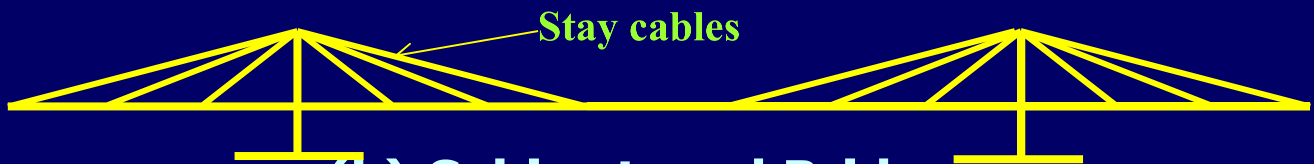


Fig.1(a) Tension Members in Buildings

INTRODUCTION



(a) Road bridge



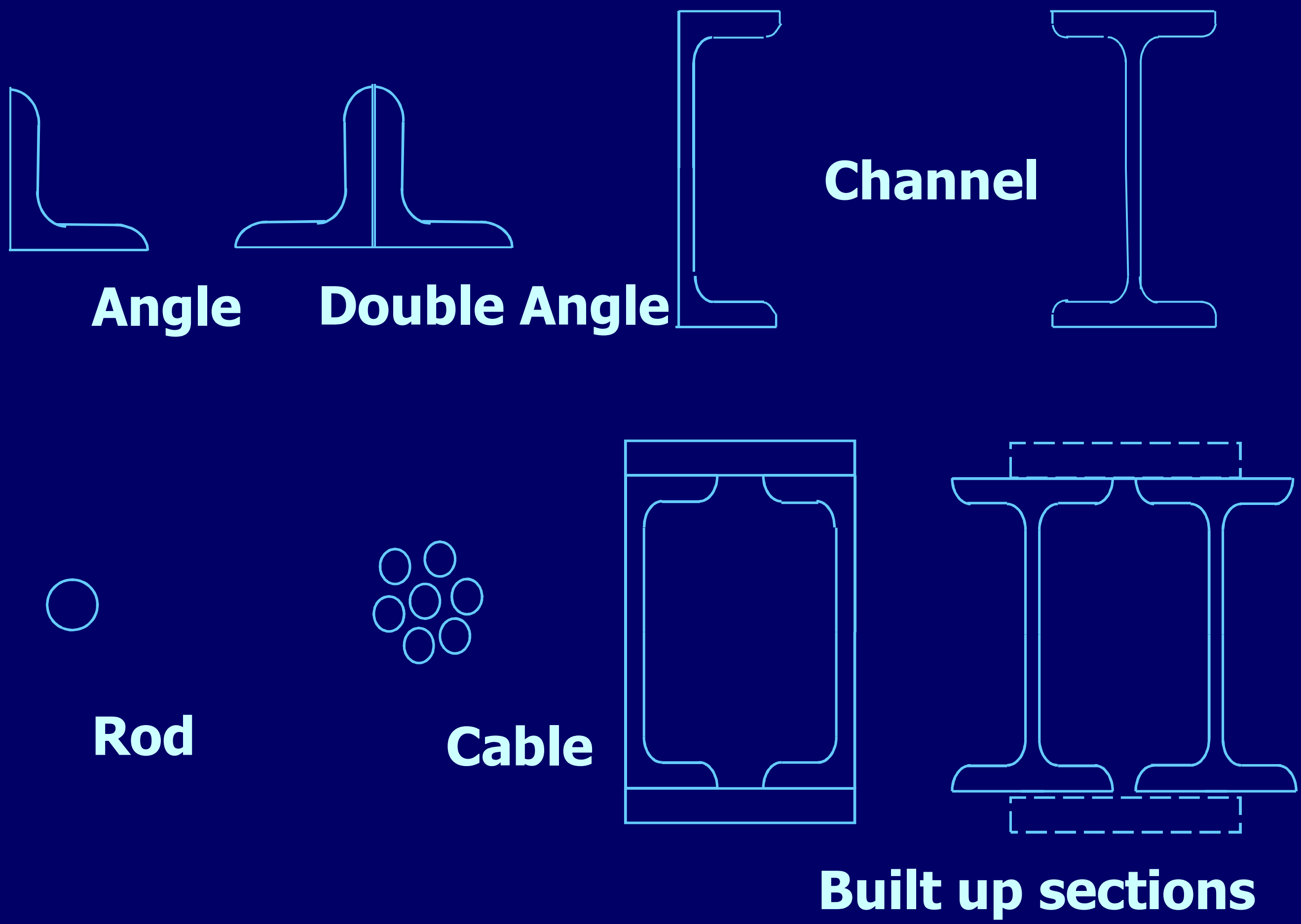
(b) Cable stayed Bridge

(c) Suspension Bridge

Fig.1(b) Tension Members in Bridges

INTRODUCTION

Cross Sections Used for Tension Members



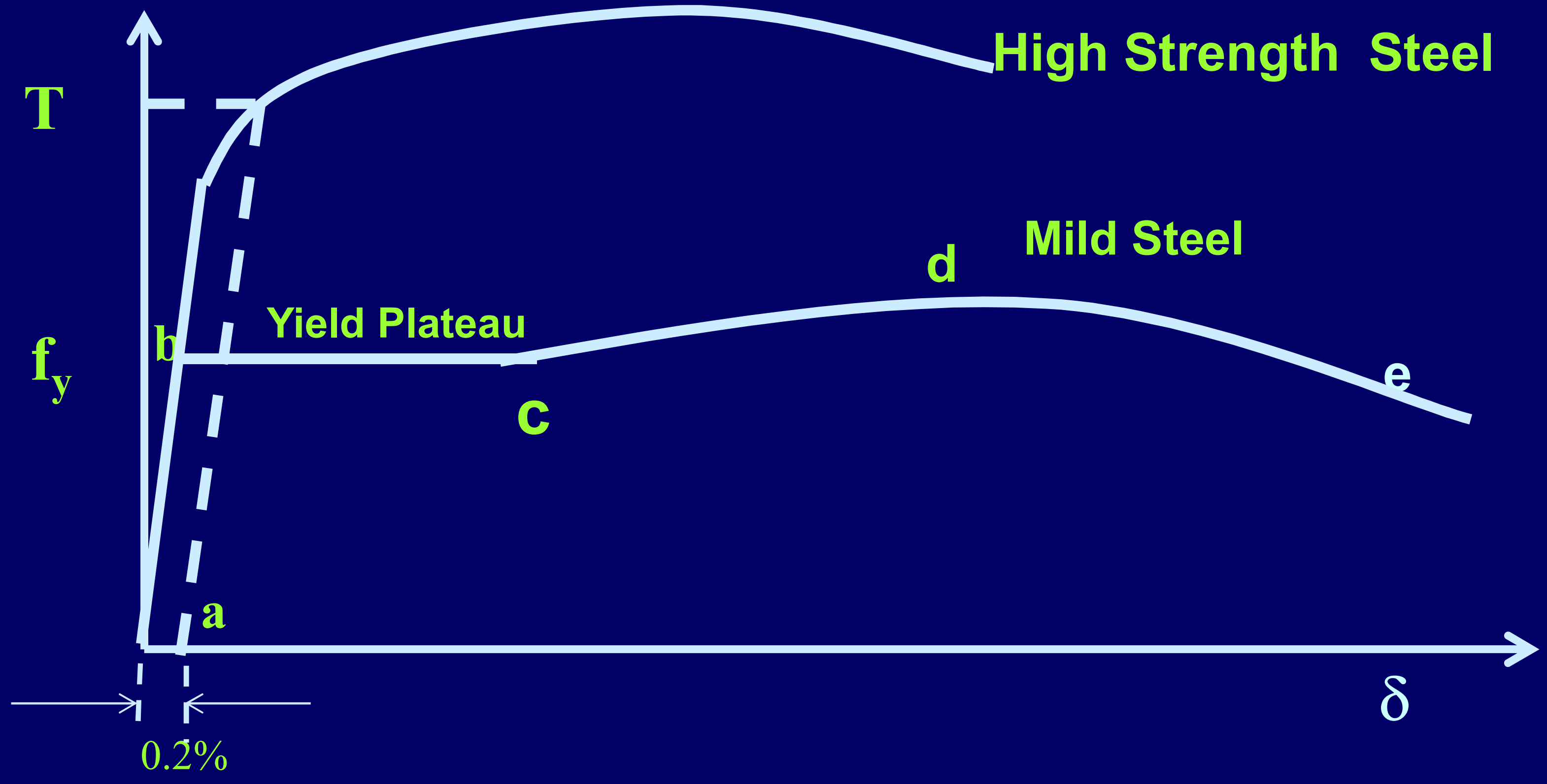
INTRODUCTION

INTRODUCTION

INTRODUCTION

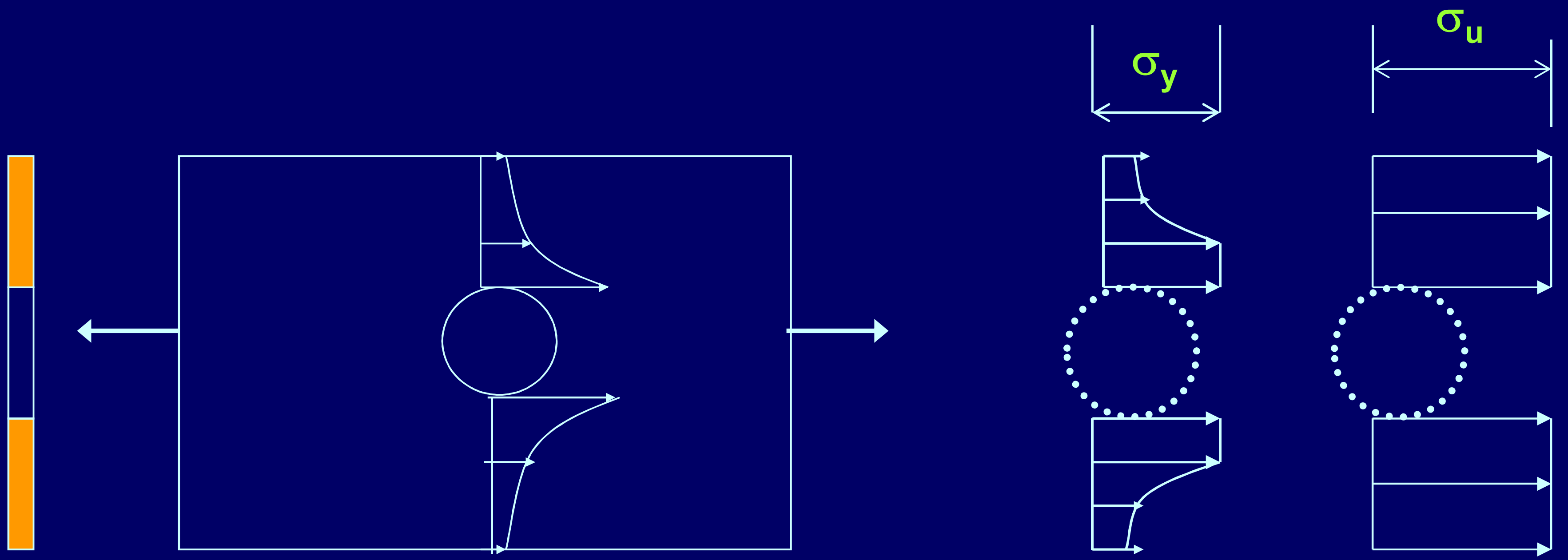
BEHAVIOUR IN TENSION

Material Properties



BEHAVIOUR IN TENSION

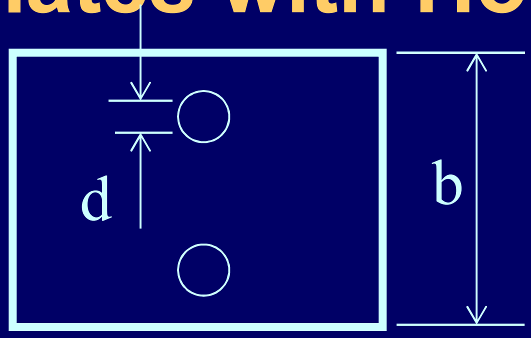
Plates with a Hole

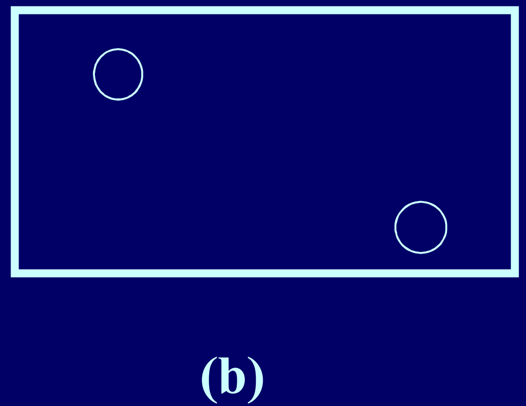


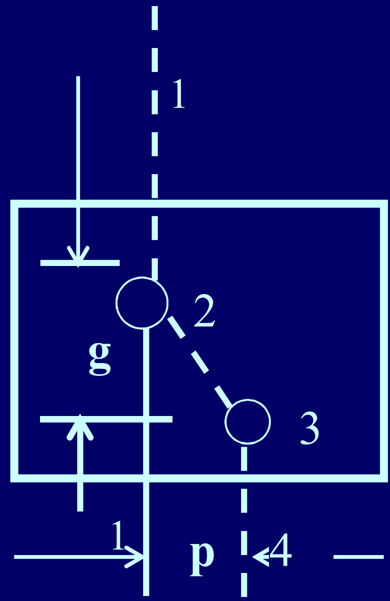
(a) Elastic (b) Elasto-Plastic (c) Ultimate

BEHAVIOUR IN TENSION

Plates with Holes







Case a: Net Area: = t (b - 2*d)

Case b: Net Area: = t (b – d)

Case c: Net Area: < t (b – d)

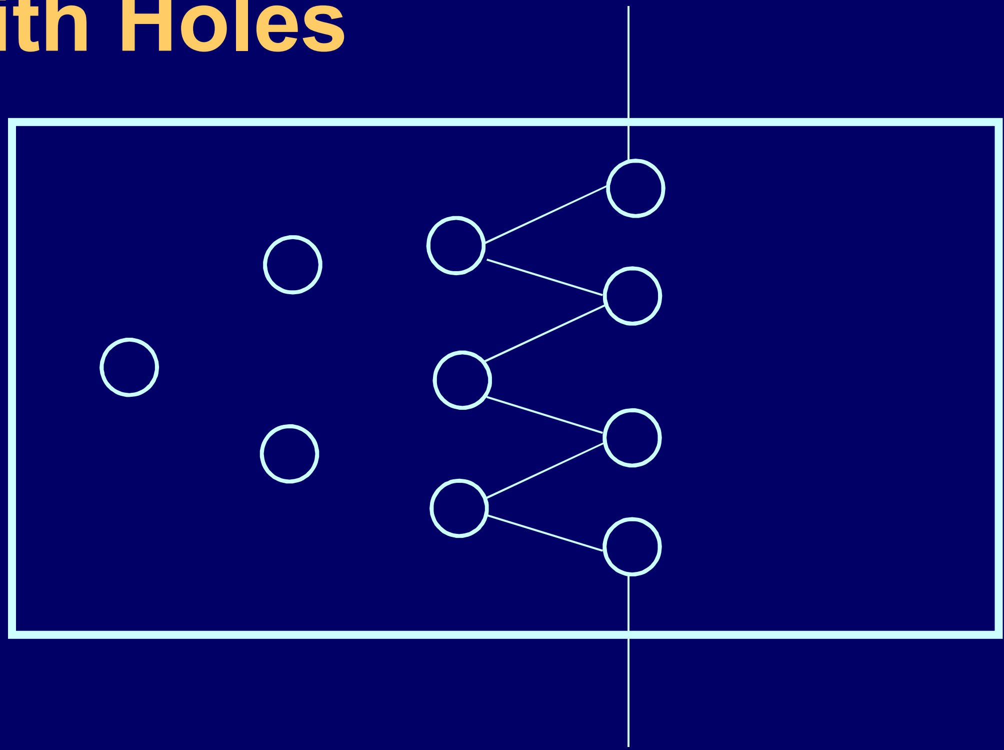
> t (b - 2*d)

P = pitch

g = gauge

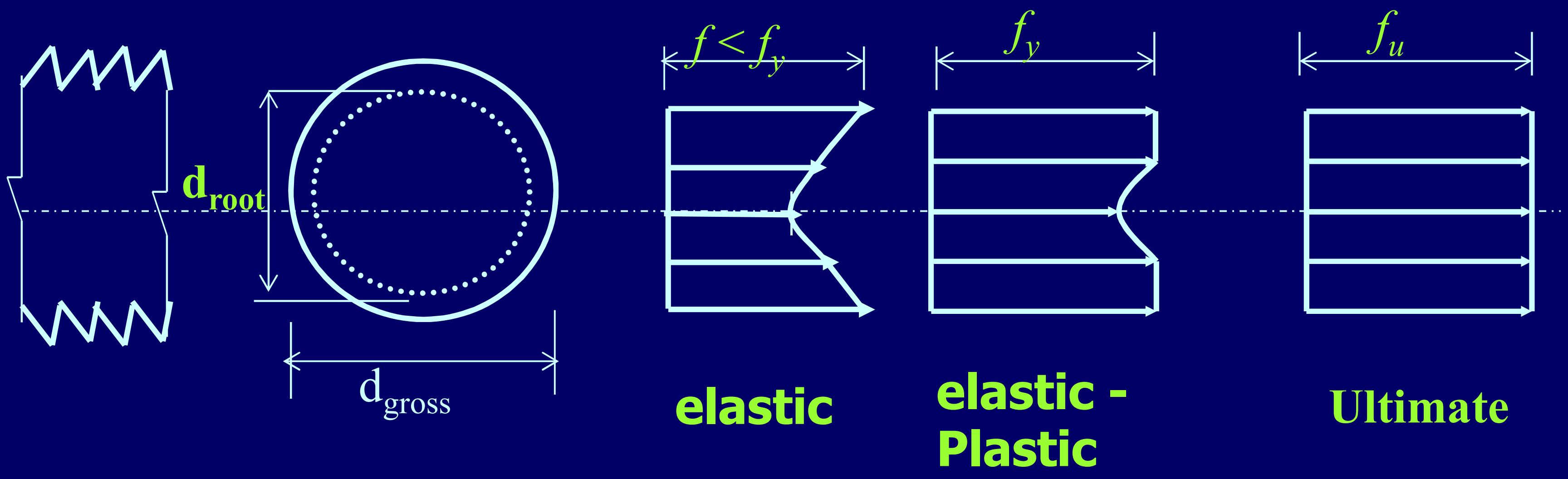
BEHAVIOUR IN TENSION

Plates with Holes



$$A_n = [\, b - n\, d + \Sigma(p^2 / 4\, g)]$$

BEHAVIOUR IN TENSION



Gross Area Design Strength (P_{tg})

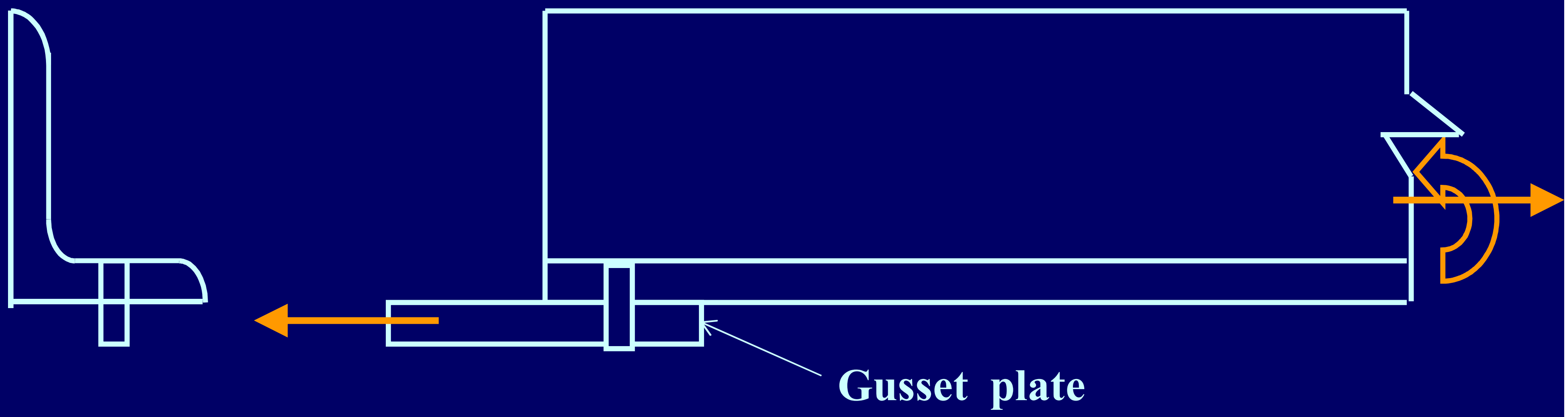
$$P_{tg} = f_y * A_g / \gamma_{MO} \qquad \gamma_{MO} = 1.15$$

Net Area Design Strength (P_{tn})

$$P_{tn} = 0.9 * f_u * A_n / \gamma_{M1} \qquad \gamma_{M1} = 1.25$$

BEHAVIOUR IN TENSION

- **ANGLES** **Eccentrically Loaded Through Gussets**



ANGLES UNDER TENSION

- Factors Affecting Angle Strength
  - Effect of Gusset Thickness
  - Effect of Angle Thickness
  - Effect of Shear Lag
  - Effect of End Connections
  - Effect of Block Shear

- **Shear Lag**
  - ➢ **Plate when subjected to tension are subjected to shear deformation near edges . (Tensile stress near to zero at edges)**
  - ➢ **Shear stress produced in material gradually transfer tension at edges to central axis of plate.**
  - ➢ **Transfer of stresses take place in the length of member approximately equal to its width**
  - ➢ **Beyond this length tensile stresses are assumed to be uniformly distributed over the whole section of plate.**
  - ➢ **Transmission of tension at edges to full width by shear stress is Shear lag**
- **In case of I- beam, internal transfer of force from flange to web is by shear**
- **In case of angles transfer of forces from on leg to other is by shear**

ANGLES UNDER TENSION

Effect of Shear Lag

Shear Lag $\longrightarrow$ Strength Reduction

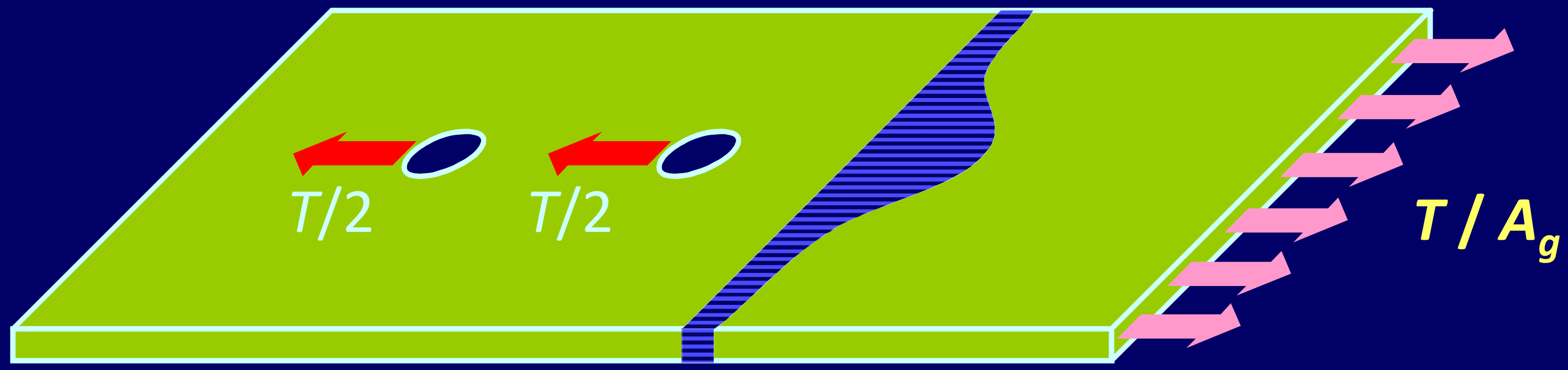
Shear Lag $\uparrow$ as $A_o / A_g \uparrow$

Shear Lag $\downarrow$ as end connection Stiffness $\uparrow$

Non-Uniform Stress

More stress near restraint

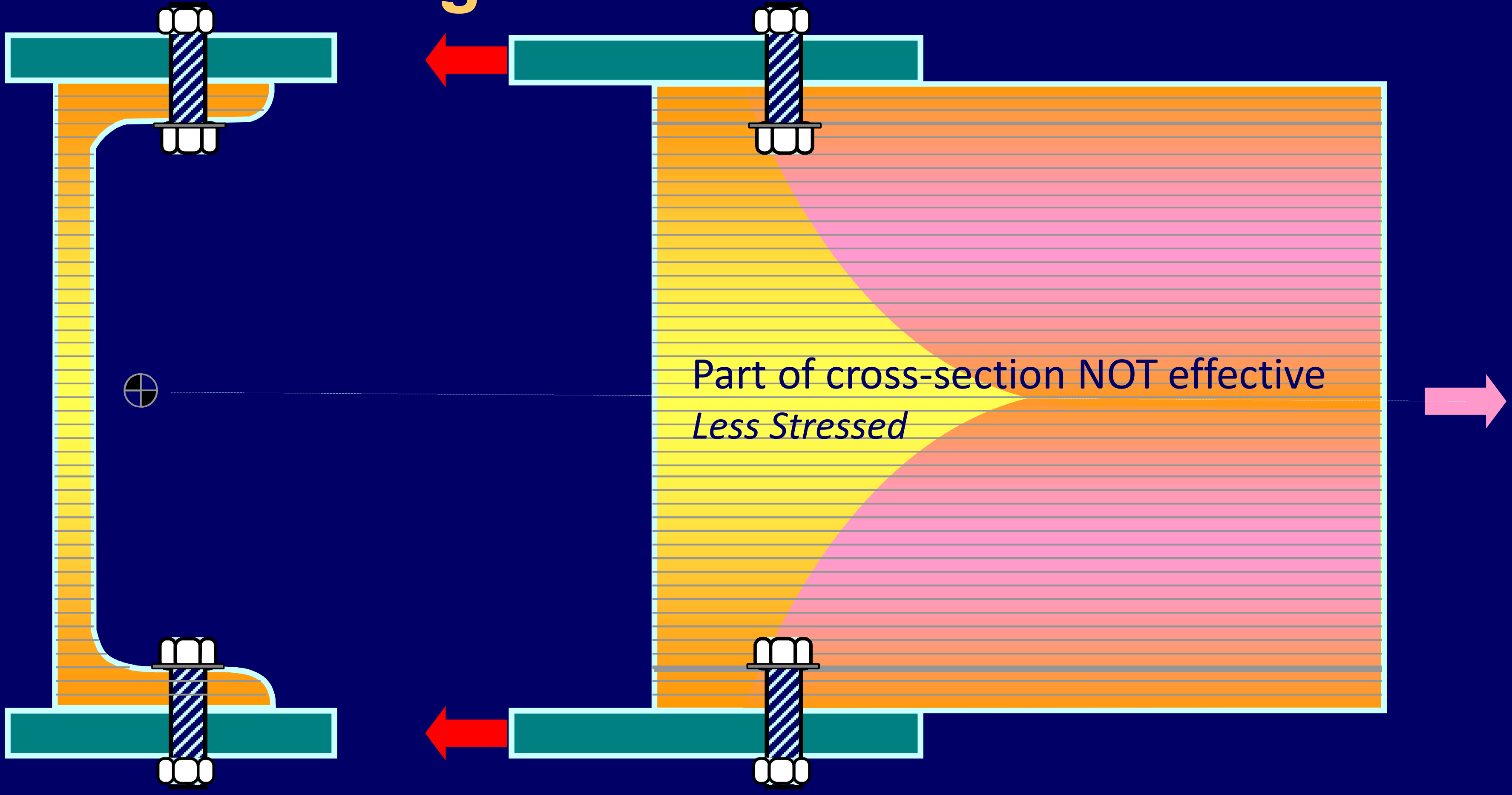
Less stress near un-restrained / free ends



Shear Lag

Channels

Both legs connected

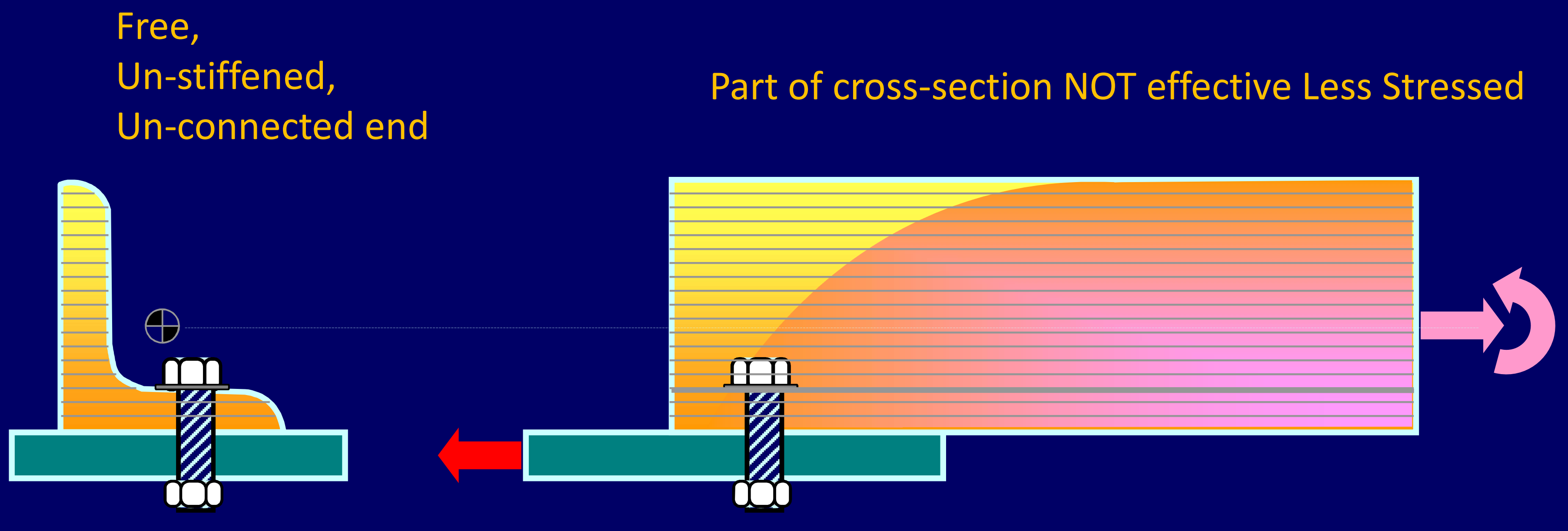


Shear Lag…

Angles

Single leg connected

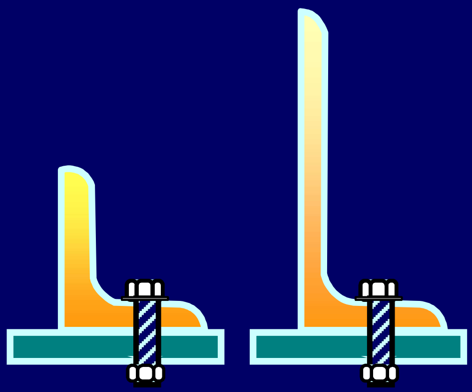
Eccentrically loaded through gusset plates



Shear Lag…

- **Effects of Shear Lag**
  - Strength reduction
    - Part of cross-section ineffective (less stressed)
      - Consider in *Design*

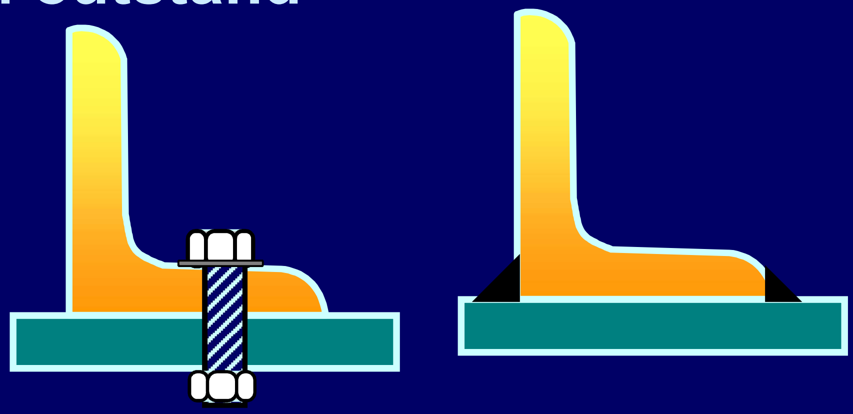
- **Factors affecting / causing Shear Lag**
  - Outstand (unconnected part)
    - More outstand – more shear lag
    - Thin / slender outstand – more shear lag
  - Connection stiffness
    - Flexible connection – more shear lag



- **Rupture of net section**

$$T_{dn} = 0.9 \times A_{nc} \times f_u / \gamma_{m1} + \beta \times A_{go} \times f_y / \gamma_{m0}$$

- A_{nc} = Net area of the *connected* leg
- A_{go} = Gross area of the *unconnected* leg
- β = reduction factor based on contribution of unconnected outstand



Angles in Tension…

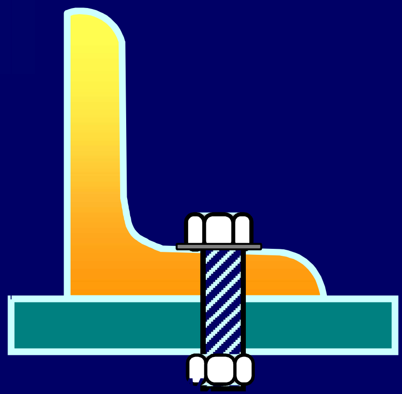
- **Rupture of net section**

$$T_{dn} = 0.9 \times A_{nc} \times f_u / \gamma_{m1} + \beta \times A_{go} \times f_y / \gamma_{m0}$$

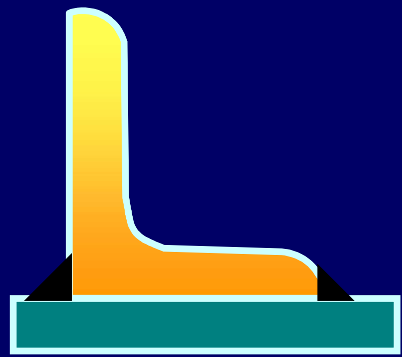
$$\beta = 1.4 - 0.076\left(\frac{w}{t}\right)\left(\frac{f_y}{f_u}\right)\left(\frac{b_s}{L_c}\right)$$

$$\leq \left(\frac{f_u}{f_y}\right)\left(\frac{\gamma_{m0}}{\gamma_{m1}}\right)$$

$$\geq 0.7$$



$b_s = w + w_1 - t$



$b_s = w$

Rupture of net section

Limits of ($\beta \times A_{go} \times f_y / \gamma_{m0}$)

- **Upper limit: $A_{go} \times f_u / \gamma_{m1}$**
  - **Full unconnected length rupture**

- **Lower limit: $0.7 \times A_{go} \times f_y / \gamma_{m0}$**
  - **70% of unconnected length yielding**

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

$$\leq \left(\frac{f_u}{f_y}\right)\left(\frac{\gamma_{m0}}{\gamma_{m1}}\right)$$

$$\geq 0.7$$

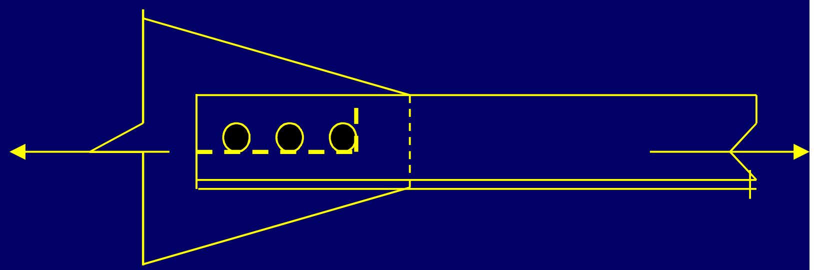
ANGLES UNDER TENSION

Strength of Net Section

$$P_{tn} = A_{nc} * f_u / \gamma_{M1} + \beta * A_o \, f_y / \gamma_{MO}$$

Strength of Gross Section

$$P_{tg} = A_g * f_y / \gamma_{M0}$$



Block Shear Strength

$$P_{tb} = (0.62 * A_{vg} * f_y / \gamma_{M0} + A_{tn} * f_u / \gamma_{M1})$$

$$=(0.62 * A_{vn} * f_u / \gamma_{M1} + A_{tg} * f_n / \gamma_{M0})$$

DESIGN OF TENSION MEMBERS

Efficiency

$$\eta = P_t /(A_g * f_y / \gamma_{M0})$$

Design Steps

$$A_n = P_t / (f_u / \gamma_{M1})$$

$$A_g = P_t / (f_y / \gamma_{M0})$$

Choose a trial section

Analyse for its strength

DESIGN OF TENSION MEMBERS

Stiffness Requirements

Designed for compression under stress reversal $\ell/r < 250$

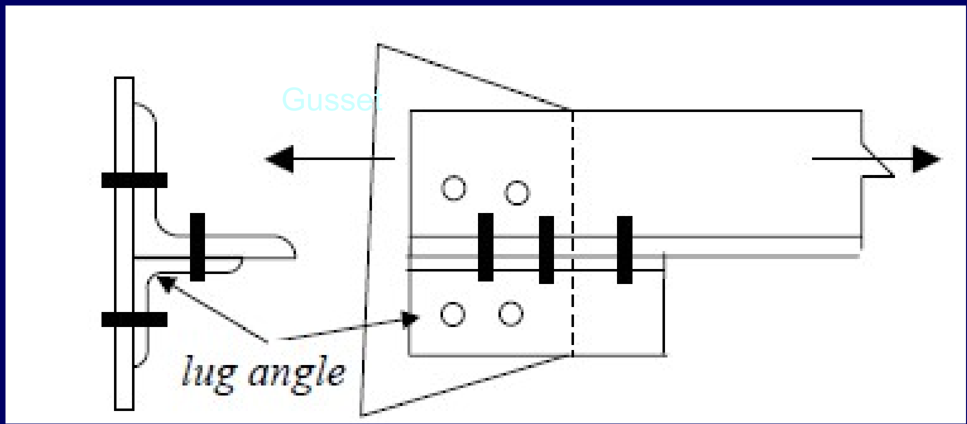
Not designed for compression under stress reversal $\ell/r < 350$

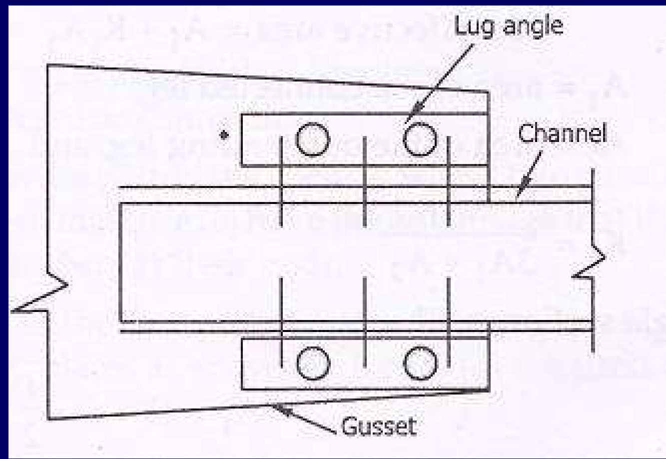
Members under tension only $\ell/r < 400$

LUG ANGLE

- A short length of angle section

- Attached to the main tension member at the connecting end





ADVANTAGES

- When a tension member is connected to a gusset plate at its end, a large number of bolts are required, specially when the tensile load is large, necessitating the provision of big size gusset plate

- Size of the gusset plate decreased
- Providing extra gauge lines for accommodating the required number of bolts.
- Increase the efficiency of the outstanding leg and to decrease the length of the end connections

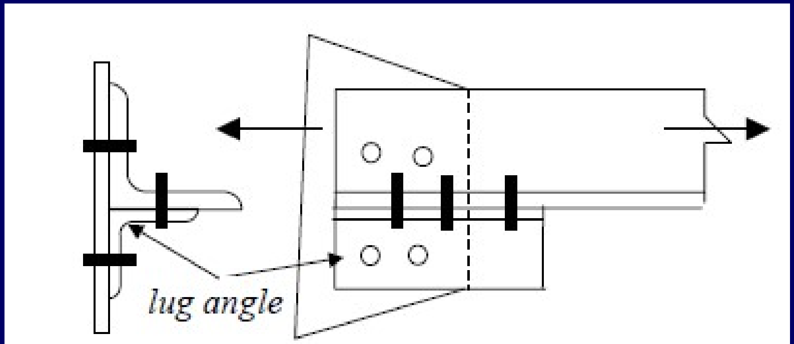
How IS 800-2007 view Lug Angle?

- **Effective connection of the lug angle**

  - terminate at the end of the member

  - connection start in advance of the member of the gusset plate

  - minimum of two bolts, rivets or equivalent welds



If the main body is an angle

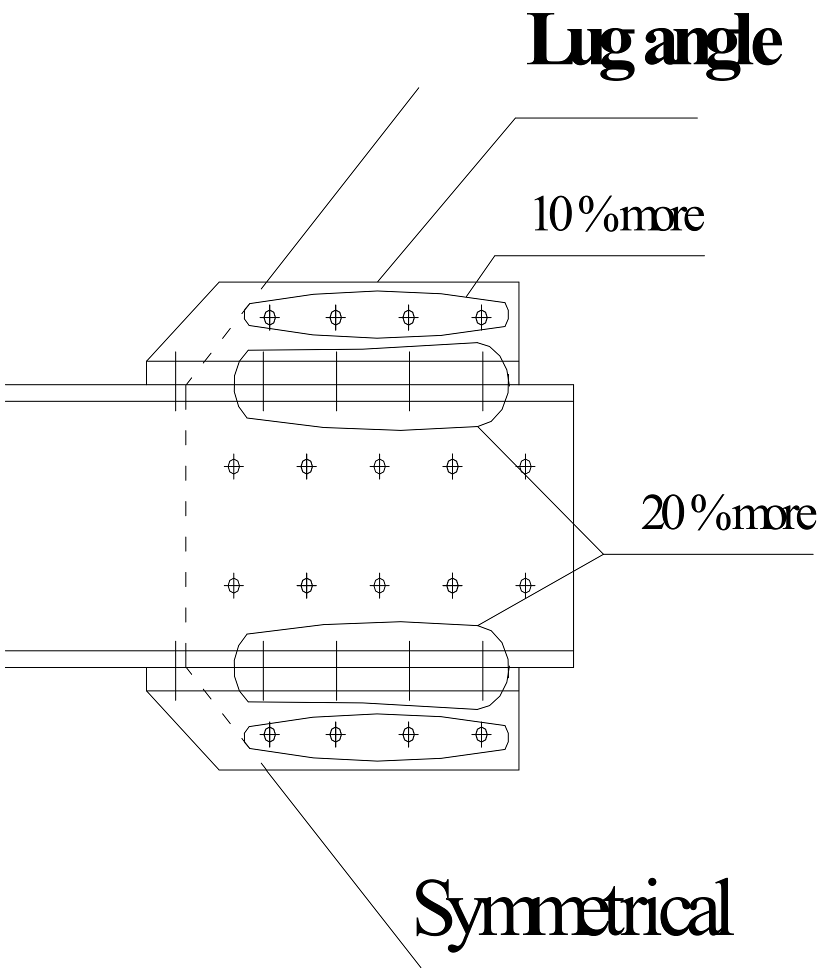
- whole area of the member shall be taken as the effective (whole area = gross area – deduction for bolt holes)

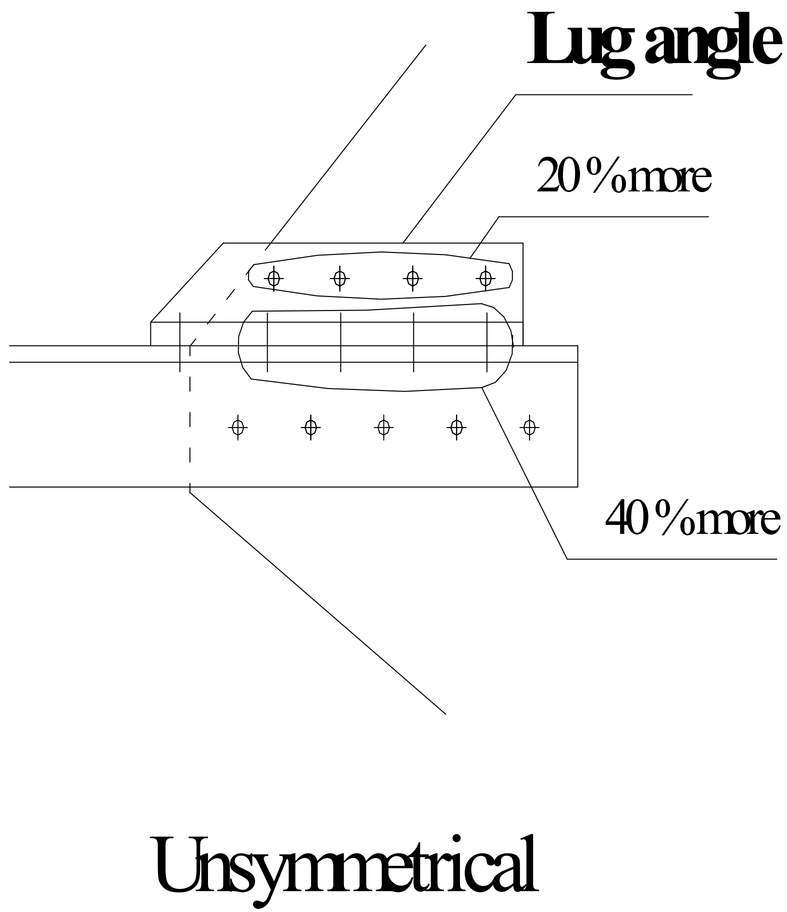
- lug angle to gusset plate = 20% more than the force in outstanding leg

- lug angle to main member = 40% more than the force in outstanding leg

If the main member is a channel

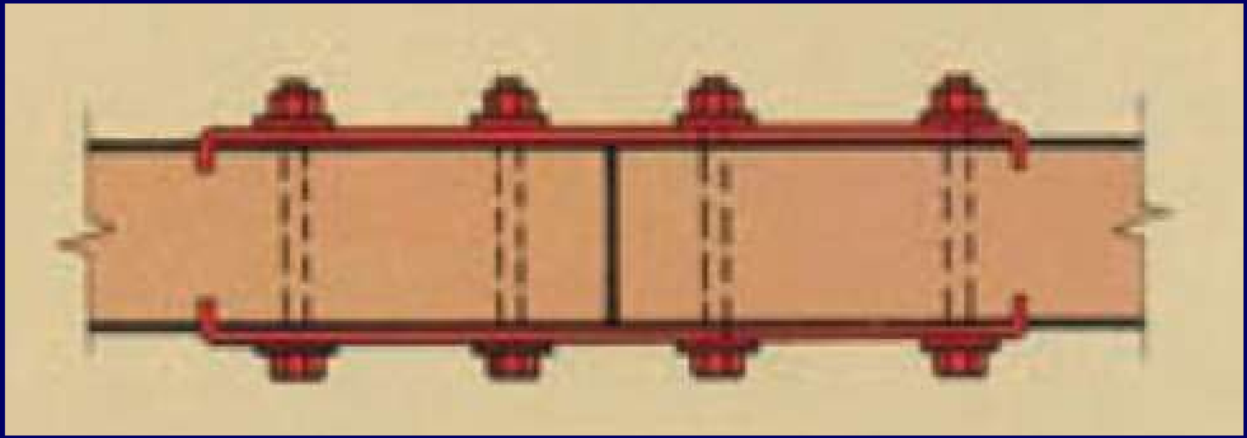
- Symmetric
- lug angle to gusset plate = 10% more than the force in outstanding leg
- lug angle to main member = 20% more than the force in outstanding leg


Lug angle
10%more
20%more
Symmetrical


Lug angle
20%more
40%more
Unsymmetrical

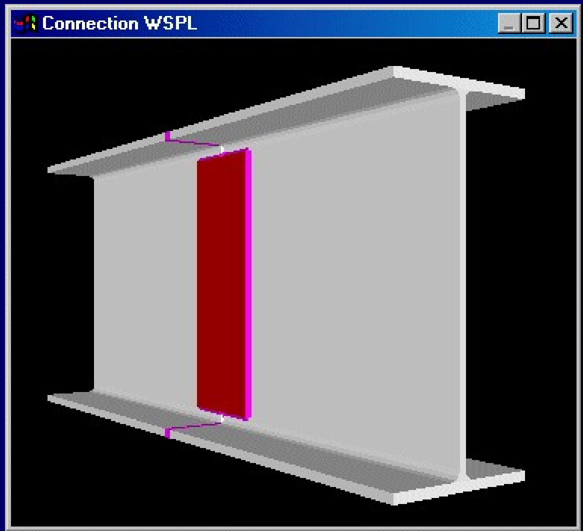
Tension splice

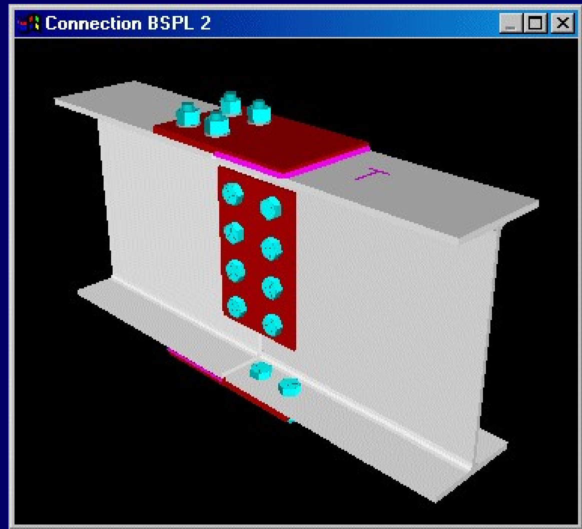
- Tension members spliced…….
  - Tension member is less than available length
  - different thicknesses

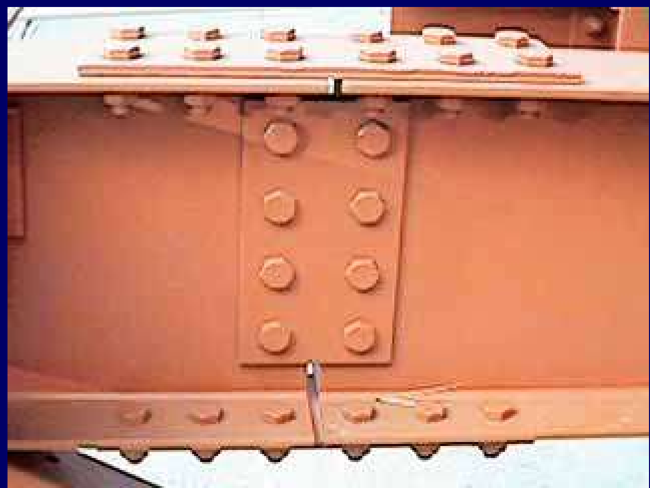


- Web splice

Flange splice

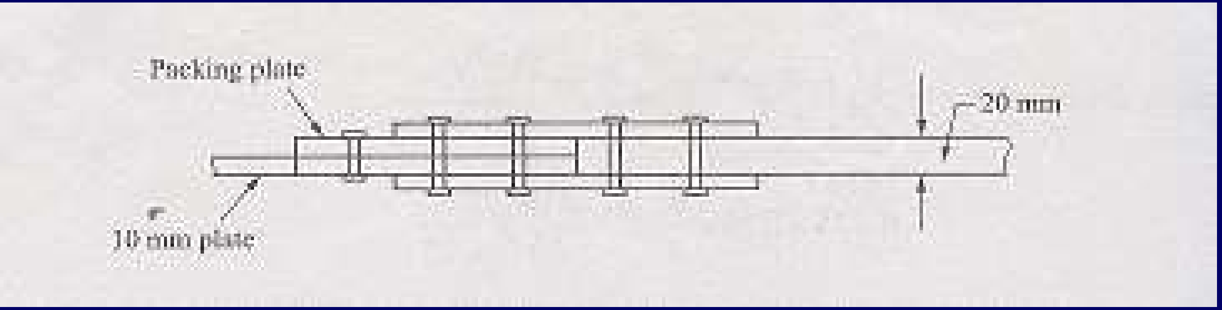






Tension splice….

- both the sides of the member - cover plates – to form a butt joint
- bolts placed to transfer the load
- Plates of different thickness
  - Filler plates or packing plates



Tension splice….

How IS 800-2007 view Tension splice ?

- Strength of the splice plate and bolts – design load

- Design shear capacity of bolts carrying shear through packing plates in excess of 6mm

$$ß_{pk} = 1\text{-}0.0125t_{pk}$$

Filler plates

- Additional bolts – thickness of packing plate >6 mm

- For each 2mm thickness of packing, number increased by 2.5 %.