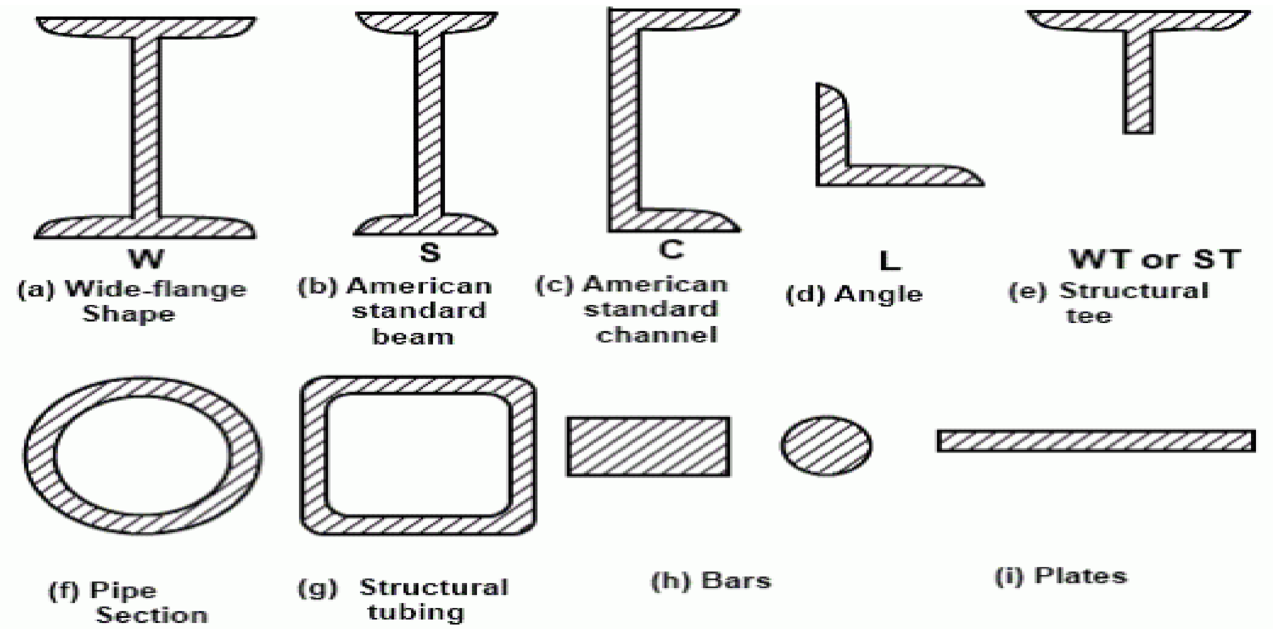
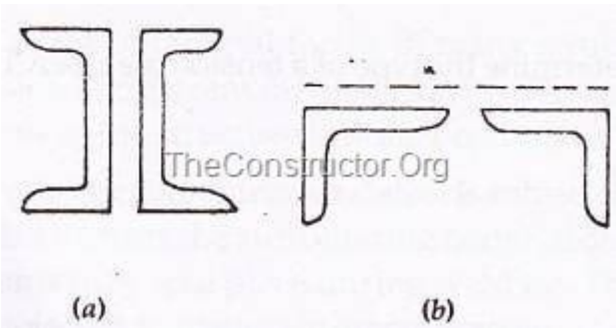
DESIGN OF STEEL TENSION MEMBER

Tension members are the structural elements which is subjected to direct axial tension as a result of which the member elongates. These members are intended to resist axial tension. Tension members are otherwise known as tie members. The strength of the tension member is governed by various factors such as length of the connection, spacing between the fasteners, net area of the cross section, type of fabrication, eccentricity in the connection, shear lag at the end connection etc. so in general it should be compact and in order to minimize the stress concentration it should be arranged in such a manner that large portion of it as possible is connected to the gusset plate.

Tension members are used in bridge trusses, single storeyed buildings, cable stayed bridges, suspension bridges, roof purlin system etc.

3.1 Common Shapes of Steel Tension Member





3.2 Maximum Value of effective Slenderness Ratio

The slenderness ratio of any structural member is defined as the ratio of its effective length (KL) to the least radius of gyration. Where the value of K depends on the end conditions. Theoretically there is is no importance of slenderness ration on the design of tension member as buckling is a little concern for them. But to resist stress reversals, wind or earthquake load, vibrations, deflections etc. a maximum value of slenderness ratio has been set for the tension members as per IS 800 table 3.

3.3 Analysis and Design of Steel Tension Member

The tension member may fail by three modes of failure. They may fail due to excessive yielding of the gross section, rupture of the critical section when holes are present in it or it may fail due to the block shear failure at the ends.

Hence depending on the failure conditions the design strength of the tension member is governed by the following strength;

a) Design strength due to yielding of gross section (T_{dg})
b) Design strength due to rupture of critical section (T_{dn})
c) Design strength due to block shear failure (T_{db})

The minimum of the above three strength is called as the design strength of the tension member.

a. Design strength due to yielding of the gross section

It is given by $T_{dg} = A_g f_y / \gamma_{m0}$

Where f_y = yield stress of the material

A_g = gross area of the cross section

γ_{m0} = partial safety factor for failure in tension member by yielding

b. Design strength due to rupture of critical section

For Plates:

$T_{dn} = (0.9 A_n f_u) / \gamma_{ml}$

Where, γ_{ml} = partial safety factor for failure at ultimate stress

f_u = ultimate stress of the material

A_n = net effective area of the member = $[b - nd_h + \sum(P^2_{si} / 4g_i)]$

b = width of the plate

t = thickness of the plate

d = diameter of the bolt hole

g = gauge distance between the bolt holes

P_s = length of the staggered pitch

n = number of bolts in the critical section

For Threaded Rods

$T_{dn} = (0.9 A_n f_u) / \gamma_{ml}$

where ,

A_n = net root area at the threaded section

$= \frac{\pi}{4} (d - 0.9283p)^2$, p being the pitch of the threads

$\approx \frac{\pi}{4} 0.78d^2$

si*ngle Angle*

When angle section is connected through one leg it is affected by shear lag and the effectiveness of outstanding leg is reduced.

In this case rupture strength at net section is given by,

$T_{dn} = (0.9 A_{nc} f_u) / \gamma_{ml} + (\beta A_{g0} f_y) / \gamma_{m0}$

Where, A_{nc} = Net area of the connected leg

A_{go} = Gross area of the outstanding leg

$\beta = 1.4 – 0.076(\omega/t)(f_y / f_u)(b_s/L_c)$

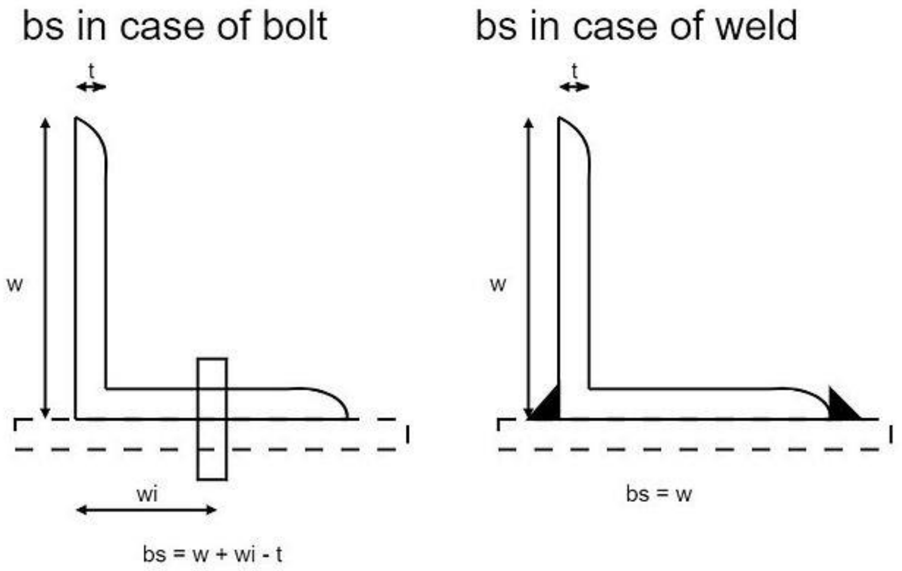
$\beta \leq (f_u \gamma_{m0}) / (f_y \gamma_{ml}) \geq 0.7$

where, ω = outstanding leg width

t = thickness of the leg

b_s = shear lag width

L_c = distance between the outer most bolt in the end joint measured along the load direction or length of the weld along the load direction



But for preliminary sizing, the rupture strength of net section may be approximately taken as

$T_{dn} = (\alpha A_n f_u) / \gamma_{ml}$
α = 0.6 for 1 or 2 nos. of bolts
α = 0.7 for 3 nos. of bolts
α = 0.8 for 4 or more nos. of bolts or for welded connection

c. **Design Strength due to Block Shear Failure:**

In case of block shear failure the failure occurs along a plane involving tension in one plane and shear in the opposite plane.

i) **Block shear failure in case of bolted connection**

In case of block failure if one plane is considered to be failed in shear then the perpendicular
a. For shear yield and tension fracture

$$T_{db_1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m_o}} + 0.9\frac{A_{tn} f_u}{\gamma_{ml}}$$

b. For tension yield and shear fracture

$$T_{db_2} = \frac{A_{tg} f_y}{\gamma_{m0}} + 0.9 \frac{A_{un} f_u}{\sqrt{3}\ \gamma_{ml}}$$

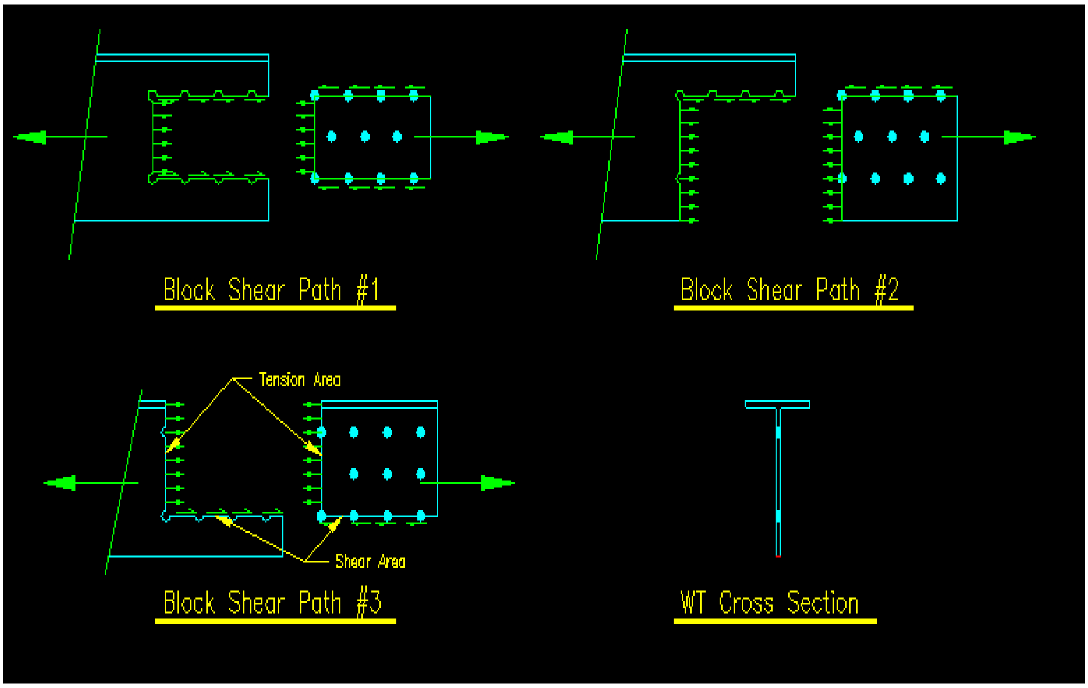
Where,

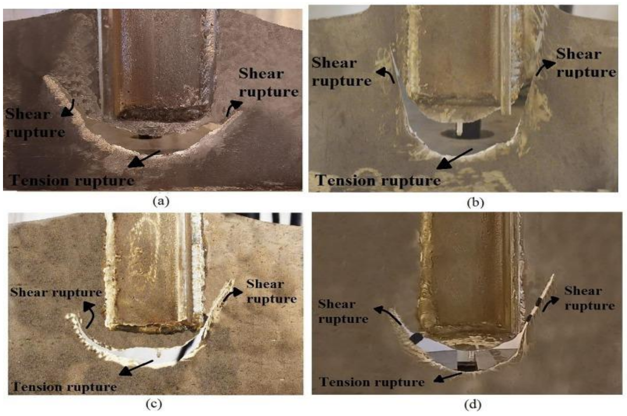
A_{vg} = minimum gross area in shear in the line of action of force
A_{vn} = minimum net area in the line of action of force
A_{tg} = minimum gross area in tension in planes perpendicular to line of action of force
A_{tn} = minimum net area in tension in planes perpendicular to the line of action of force

ii) Block shear failure in case of welded connection

Block shear failure in case of welded connection shall be calculated by taking an appropriate section in the member around the weld. However for welded tension member the net area in shear and the net area in tension will be replaced by gross area in shear and gross area in tension respectively as there is no net area in case of welded connection.

Different Patterns of Block shear failure





Shear lag:

Shear lag effect is considered when some parts of the member are not directly connected to the joint. The non-uniform stress distribution that occurs in a tension member adjacent to a connection, in which all elements of the cross section are not directly connected, is commonly referred to as the shear lag effect. This effect reduces the design strength of the member because the entire cross section is not fully effective at the critical section location.