**Behaviour of Tension Members**

The load-deformation behaviour of a tension member is similar to the basic material stress-strain behaviour. When a member is subjected to tension, the area of cross-section and gauge length change continuously due to the poison effect and longitudinal strain respectively. Stresses and strains calculated using initial cross-section and gauge length is called engineering stress-strain curve, while that calculated using instantaneous cross-section and gauge length is called a true stress-strain curve.

Modes of Failure of Tension Members

The different modes of failure by which a tension member could fail are listed and explained further.

Gross Section Yielding

Net Section Rupture

Block Shear Failure

1. Gross Section Yielding

**Concept:**

A tension member without bolt holes can resist loads up to the ultimate load without failure. But such a member will deform in the longitudinal direction before fracture and makes the structure unserviceable. Hence to calculate design strength, yielding of the gross section is considered appropriate.

**Formula:**

As per *Clause 6.2 Design Strength Due to Yielding of Gross Section of IS 800: 2007*, the design strength of members under axial tension (Tdg) as governed by yielding of the gross section, is given by,

**Tdg = (Ag * fy) /γm0,**

where,

Ag - gross area of cross-section,

fy - yield stress of the material, and

γm0 - partial safety factor for failure in tension by yielding = 1.1 (refer to Table 5 of IS 800).

2. Net Section Rupture

**Concept:**

When a tension member is connected using bolts, cross-section reduces because of the holes present and this is referred to as net area. Holes in the members cause stress concentration at service loads. From the theory of elasticity, the tensile stress adjacent to a hole will be about two to three times the average stress on the net area. The ratio of maximum elastic stress to the average stress (fmax/favg) is called the stress concentration factor. Stress concentration is an important factor when a member is subjected to dynamic load where there is a possibility of brittle fracture or when the repeated application of load may lead to fatigue failure.

In static loading of a tension member with a hole, the point adjacent to the hole reaches the field stress (fy) first. With further loading, the stress at that point remains constant at yield stress and each fibre away from the hole progressively reaches the yield stress. Deformations continue with increasing load until rupture/tension failure of the member occurs when the entire net cross-section of the member reaches the ultimate stress (fu).

**Formula:**

As per *Clause 6.3 Design Strength Due to Rupture of Critical Section of IS 800: 2007*, design strength is given for different members separately as follows.

1. Design Strenght in Tension of a Plate (Tdn)

*Tdn = 0.9 * An * fu / γm1,*

where,

γm1 - partial safety factor for failure at ultimate stress = 1.25 (refer to Table 5 of IS 800: 2007),

fu - ultimate stress of the material,

An - the net effective area of the member given by,

*An = [b - (n * dh) + Σ( (Psi^2) / (4 * Gi) )] * t,*

where,

b, t - breadth and thickness of the plate respectively, dh- diameter of the bolt hole,

g - gauge length between the bolt holes,

Ps - staggered pitch length between the line of bolt holes,

n - number of bolt holes in the critical section, and

i - subscript for summation of all the inclined legs.

2. Design Strenght in Tension of a Threaded Rods (Tdn)

$Tdn = 0.9 * An * fu / \gamma m1$,

where,

γm1 - partial safety factor for failure at ultimate stress = 1.25 (refer to Table 5 of IS 800: 2007),

fu - ultimate stress of the material,

An - the net root area at the threaded section.

3. Design Strenght in Tension of a Single Angles (Tdn)

The rupture strength of an angle connected through one leg is affected by shear lag. The design strength (Tdn) as governed by rupture, is given by,

$Tdn = (0.9 * Anc * fu / \gamma m1) + ( \beta * Ago * fy / \gamma m0)$,

where,

$\beta = 1.4 - 0.076 * (w/t) * (fy/fu) * (bs/Lc) \leq ( (fu*\gamma m0) / (fy*\gamma m1) )$ and $\geq 0.7$,

where,

w - outstand leg width,

bs - shear lag width,