Design of Tension Member

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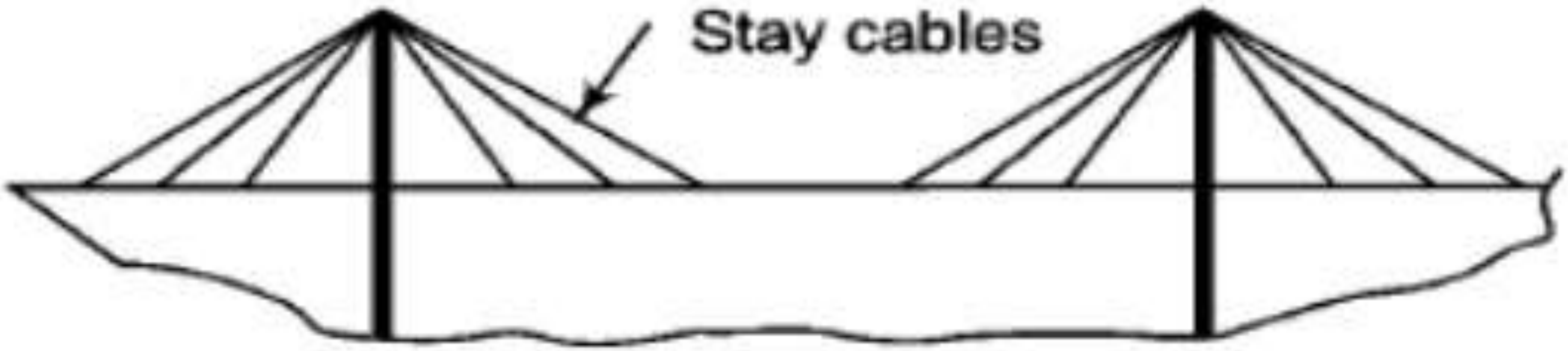
Tension members

- structural elements that are subjected to direct axial tensile loads, which tend to elongate the members.
- The strength of these members is influenced by several factors such as the length of connection, size and spacing of fasteners, net area of cross section, type of fabrication, connection eccentricity, and shear lag at the end connection.
- The stress concentration near the holes leads to the yielding of the nearby fibres but the ductility of the steel permits redistribution of over stress in adjoining section till the fibres away from the holes progressively reach yield stress. Therefore at ultimate load it is reasonable to assume uniform stress distribution.

- Net sectional area.
- To maximize the available net area in a bolted connection the bolts are places in a single line. Often the length of the connection necessitates using more than one line.
- In such cases rivets are places in staggered pattern rather than in chain pattern to minimize the reduction of c/s area.

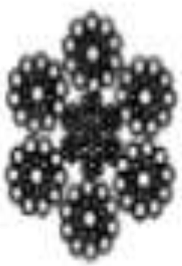
Types of tension members:

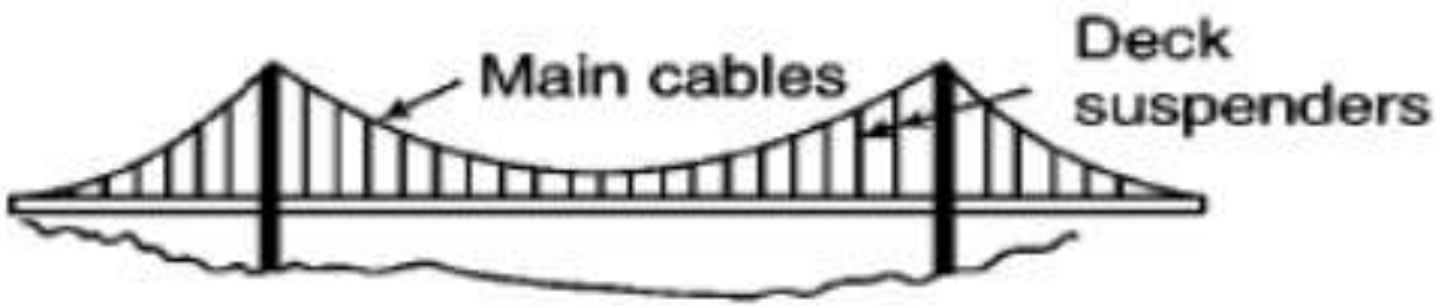
1. **Wires and cables**: wires ropes are exclusively used for hoisting purposes and as guy wires in steel stacks and towers. Strands and ropes are formed by helical winding of wires . A strand consists of individual wires wound helically around the central core. These are not recommended in bracing system as they cannot resist compression. The advantages of wire and cable are flexibility and strength.



Cable stayed bridges

(c)

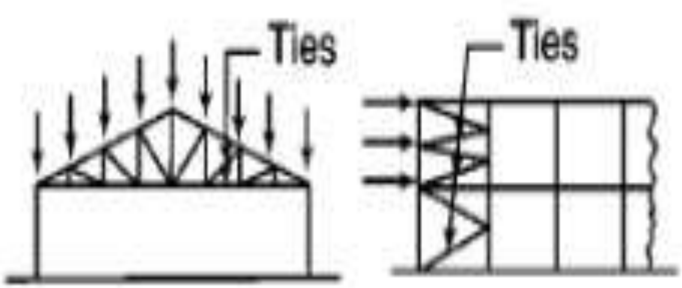




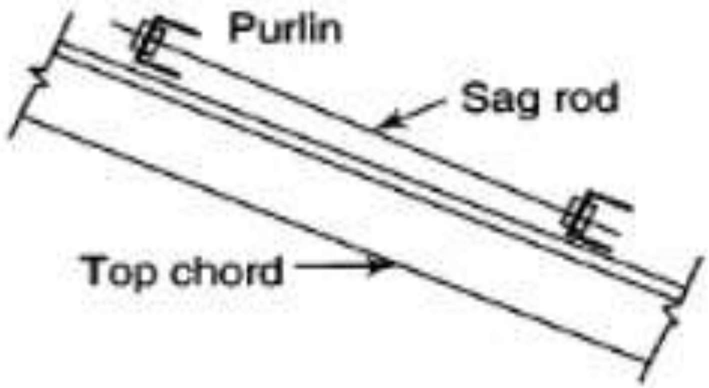
Suspension bridge

(e)

2. **Bars and rods**: These are simplest forms of tension members. Bars and rods are often used as tension members in bracing system, as sag rods to support purlins between trusses. Presently these are not favourite of with the designers because large drift they cause during strong winds and disturbing noise induces by the vibrations.



Single-storey building—roof truss and bracing



Roof-purlin system

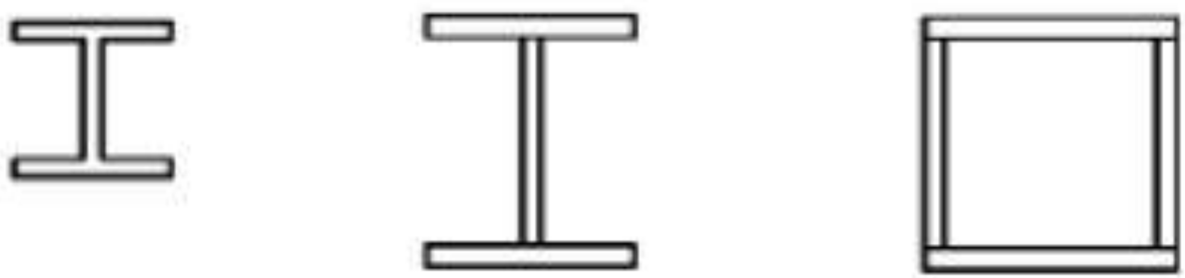
3.Plates and flat bars: These are used often as tension members in transmission towers, foot bridges, etc. These are also used in columns to keep the component members in their correct position. Eg- lacing flats, batten plates, end tie plates etc.

Single and built-up structural shapes:

1. Open sections such as angles, channels and I sections.

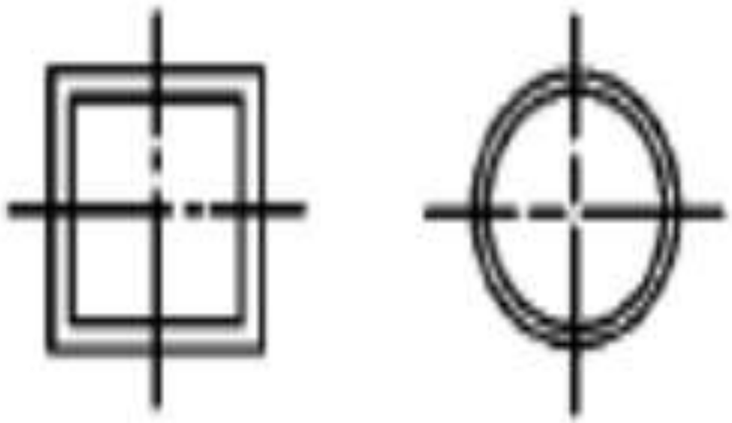
Compound and built-up sections such as double angles and double channels with are without additional plates and jointed with some connection system.

Compound sections



Heavy rolled and built-up sections

- Closed sections such as circular, square, rectangular or hollow sections.



Net sectional area:

- The net sectional area of the tension member is the gross sectional area of the member minus sectional area of the maximum number of holes.

$$A_n = A_g - \text{sectional area of holes}$$

$$A_n = (b - nd_h)t \quad \ldots\ldots (1)$$

A_n – net sectional area of the plate

A_g - gross sectional area of the member

b – width of plate

n – number of bolts

d – dia of bolt hole

t – thickness of plate

- For staggered pattern if the amount of stagger is small enough, the influence of an offset of hole may be felt by a nearby c/s and fracture along the inclined path is possible. In such cases the area to be deducted is the sum of the sectional area of all the holes in a zig zag lines extending progressively across the number the member, less $p^2t/4g$ for each inclined line.

$$\text{Deduction} = \text{sectional area of holes} - \left(\frac{p_1^2 t}{4g_1} + \frac{p_2^2 t}{4g_2}\right)$$

$$A_n = A_g - [\text{deduction}]$$

$$A_n = (b - nd_h)t + \left(\frac{p_1^2}{4g_1} + \frac{p_2^2}{4g_2}\right)t$$

$$A_n = \left[(b - nd_h) + \left(\frac{p_1^2}{4g_1} + \frac{p_2^2}{4g_2}\right)\right]t \text{ ....(2)}$$

Where p = staggered pitch

g = guage distance

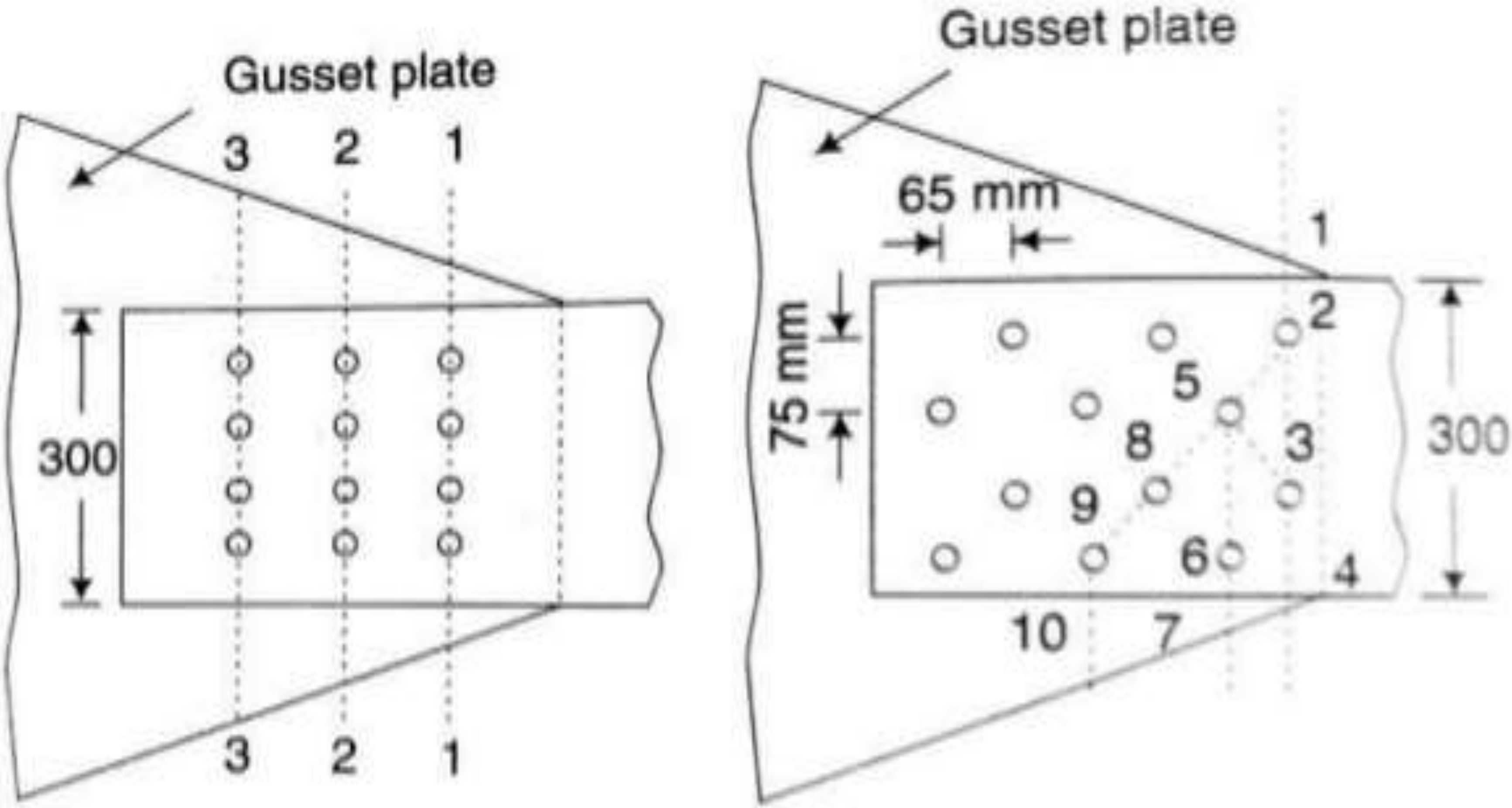
n = number of holes in a zig-zag line

Example:

A 300 ISF 300 8 mm of grade Fe 410 is used as a tension member in a lattice girder. It is connected to a 12 mm thick gusset plate by 18 mm diameter bolts. Calculate the effective net area of the member, If

a) Chain bolting is done as shown in Fig

b) Zig zag bolting is done as shown in Fig



(a) Chain pattern

(b) Zig-zag pattern

Angles and tees

- Equation (1) and (2) may be used conveniently when all the legs in the angle section is connected. For angles or tees connected through only one leg of its elements the net area obtained will be reduced and is called effective net area.
    - Effective net area $A_{ne} = k_1 k_2 k_3 k_4 A_n$
- Ductility factor (k_1) : For ductile material the stress distribution is uniform hence we can take $k_1 = 1.0$
- Factor for method of fabrication (k_2) : Holes are made either by punching or drilling. If punching (k_2) takes as 0.85 and if drilling (k_2) taken s 1.0. Is 800 : 2007 specifies that instead of reducing area by 15 % hole dia is increased by 2mm. Hence (k_2) = 1.0.

- Geometrical factor (k_3): The efficiency of the bolted joints (for net sections) is inversely to the gauge/diameter (g/d) ratio. The value of k3 generally varies between 0.9 – 1.14. However IS: 800 – 2007 specifies to be unity.
- Shear lag factor (k_4) : As per IS code 800 – 2007 the coefficient k_4 defined as $\boldsymbol{\alpha}$ is for preliminary sizing of the section. Therefore Eq 3 can be rewritten as $A_{ne} = \boldsymbol{\alpha} A_n$
- Where $\boldsymbol{\alpha}$ $= 0.6$ for number of bolts ≤ 2

  $= 0.7$ for number of bolts $= 3$

  $= 0.8$ for number of bolts ≥ 4

  $= 0.8$ for welds.

- **Shear lag**: This occurs when some element of the member is not connected. Consider an angle section tension member connected with one leg only as shown in figure. Hence at the joint/connection more of the load is carried by the connection leg and it takes a transition distance as indicated in fig, for the stress to spread uniformly across the whole angle, stress distribution in the two legs of the angle would be different. In the transition region the stress in the connected part may even exceed f_y and go into strain hardening range, the member may fracture prematurely. Away from the joint/connection the stress transfer is uniform. In the transition zone shear transfer lags. Since shear lag reduces the effectiveness of the outstanding leg it is kept smaller length generally. For this reason unequal angles with long leg as connecting leg is preferred.
- Hence shear lag is the function of distribution of steel and length of the load transfer L. It is the independent of type of load and applied to both bolted and welded connections.

Design procedure for tension members

1. Find the required gross area to carry the factored load considering the strength in yielding

$$A_g = \frac{T_u}{f_y/\gamma_{m0}} = \frac{T_u \gamma_{m0}}{f_y}$$

2. Select the suitable shape of the section depending upon the type of structure and the location of the member such that gross area is 25 to 40 % more than A_g calculated in step 1.

3. Determine the number of bolts or the welding required and arrange.

4. Find the strength considering

   a) strength in yielding of gross area.

   b) Strength in rupture of critical section

   c) Strength in block shear

5. The strength obtained should be more than factored tension. If it is too much on higher side or the strength the strength is less than the factored tension, the section may be suitably changed and checked.

6. IS 800 : 2007 also recommends the check for slenderness ratio of tension members and it should be checked according to the table given below.

Sl No.	Member	Maximum Effective Slenderness Ratio (KL/r)
(1)	(2)	(3)
i)	A member carrying compressive loads resulting from dead loads and imposed loads	180
ii)	A tension member in which a reversal of direct stress occurs due to loads other than wind or seismic forces	180
iii)	A member subjected to compression forces resulting only from combination with wind/earthquake actions, provided the deformation of such member does not adversely affect the stress in any part of the structure	250
iv)	Compression flange of a beam against lateral torsional buckling	300
v)	A member normally acting as a tie in a roof truss or a bracing system not considered effective when subject to possible reversal of stress into compression resulting from the action of wind or earthquake forces[1)]	350
vi)	Members always under tension[1)] (other than pre-tensioned members)	400

[1)] Tension members, such as bracing's, pre-tensioned to avoid sag, need not satisfy the maximum slenderness ratio limits.

- Shear strength of the bolt = $A_{nb} \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}$
- Bearing strength of the bolt = $\frac{2.5\ k_b d t f_u}{\gamma_{mb}}$

Where k_b is least of a) $\frac{e}{3d_h}$

b) $\frac{p}{3d_h}$

c) $\frac{f_{ub}}{f_u}$

d) 1.0

Thanks…………