Design of Tension Members per AISC360-16

An Online Continuing Education Course for Engineers

Course Number: S-3019

Credit: 3 Hours / 3 PDH / 3 CPD

Design of Tension Members per AISC360-16

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1. Introduction

Steel structures are widely used these days for many purposes, including rapid construction, ease of erection, and controlled quality of fabrication.

The processes of structural design can be summarized in the following steps (Figure 01):

1. Selection of economic and proper structural system.
2. Determination of applied loads.
3. Structural analysis of structural systems to get internal actions.
4. Design of structural members to resist internal actions.

By putting the loads on the chosen statical system, we get the straining action in its members by the different analysis methods. There are several straining actions, such as tension, compression, flexure, shear, and torsion.

In this course, we will study the design of steel tension members, which exist in many steel structures, such as trusses, bracing, and hangar members.

Figure (02) shows examples of members that act as tension members, such as bottom chords, diagonals, hanged posts, and bracing members.

This course is the first course of a series related to the design of members. All of these courses are independent and do not require any prerequisites. The following is the list of related courses:

1. Design of Steel Tension Members per AISC360-16.
2. Design of Steel Compression Members per AISC360-16.
3. Design of Steel Flexure Members per AISC360-16.
4. Design of Steel Members Subject to Shear per AISC360-16.
5. Design of Steel Members subject to Combined Stresses per AISC360-16.
6. Design of Steel Members subject to Torsion per AISC360-16.

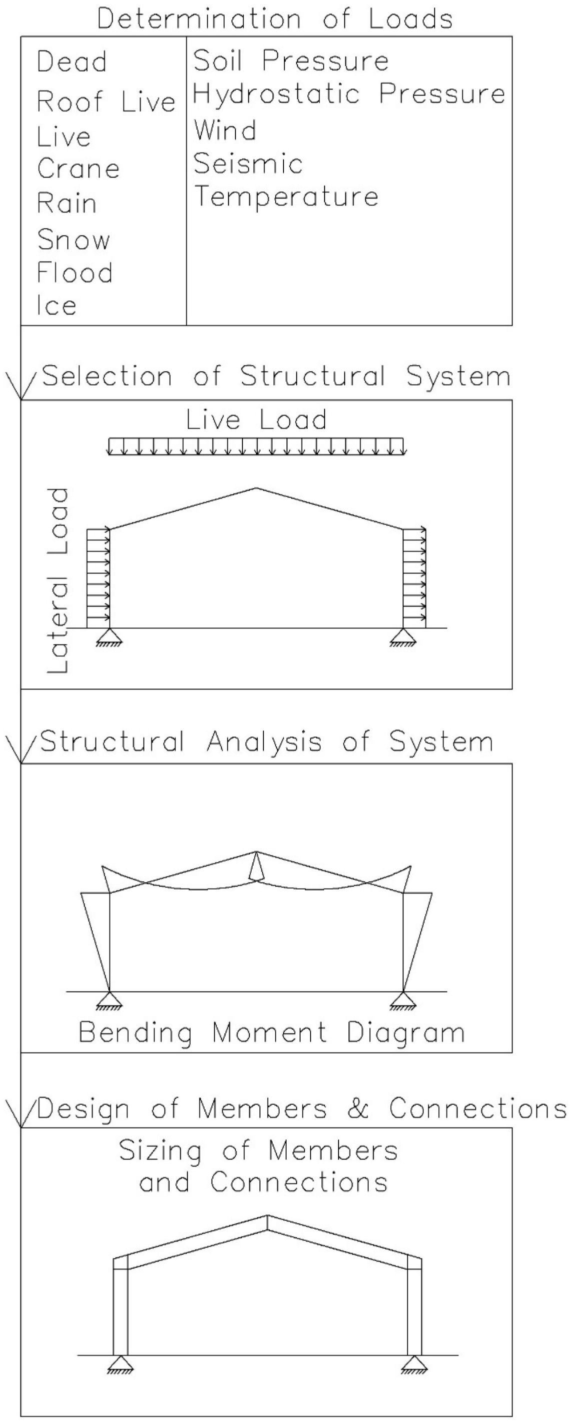

Figure (01). Steps of Structural Design

This course covers the following topics:

1. Slenderness limitation.
2. Design tensile strength.
3. Calculations of gross area, net area, and effective net area.

4. Shear lag factor (U).
5. Block shear strength.
6. Bearing and tearout strength.
7. Design of pin-connected tension members.
8. Design of eye bars.
9. Design of built-up members subject to tension.

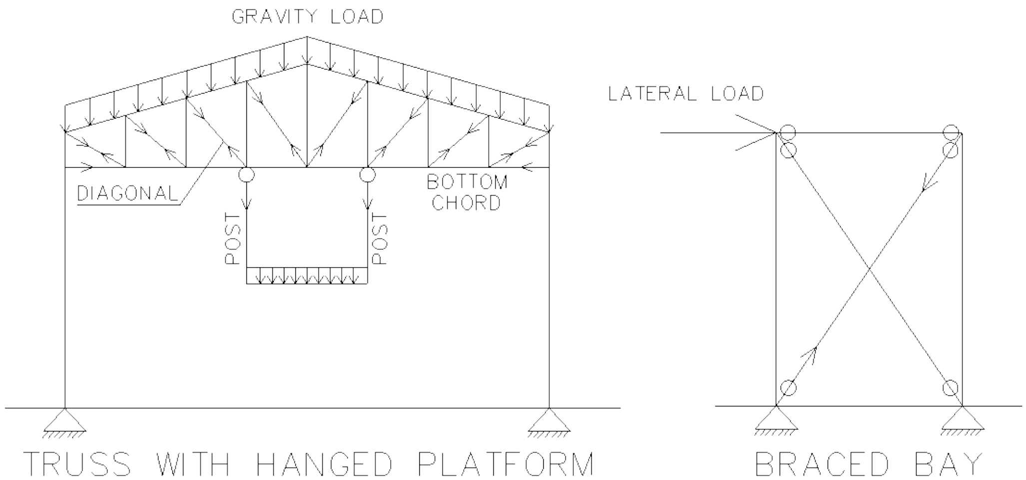

Figure (02). Examples of Tension Members

Tension members shall be designed to satisfy some requirements stated by AISC360-16, as follows:

1. Recommended slenderness ratio.
2. Check of tensile yielding.
3. Check of tensile rupture.
4. Check of block shear.

2. Slenderness Limitation

AISC360-16 recommends a slenderness limiting value for L/r not to exceed 300; this is only a recommendation based on the historical value, which gives practical considerations of ease of handling and to minimize inadvertent damage during fabrication, transport, and erection.

Also, this value reduces the effects of local movements of tension members when the structure is fully erected and fulfilling its function; these movements are such slapping or vibration of tension diagonal members in a truss.

Local slapping or vibration of tension members causes some noise in huge buildings such as airport hangers and steel mills.

3. Tensile Strength

Tensile strength shall be the lower value of the following:

a. Tensile yielding strength:

Tensile yielding strength (φR_n) or (R_n/Ω) is determined as follows:

$\varphi R_n = \varphi F_y A_g$ $\quad$ $R_n/\Omega = F_y/\Omega\ A_g$ $\quad$ (AISC360-16-Eq.D2-1)

Where;
φ= 0.90 (LRFD)
Ω = 1.67 (ASD)
F_y: Specified minimum yield stress, ksi (MPa)
A_g: Gross area of section

It is well known from principles of material mechanics that tensile yielding is a mode at which the steel member is subject to a decrease in cross-section areas and an elongation in the direction of length, as shown in figure (03).

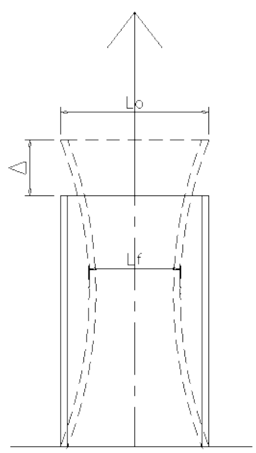

Figure (03). Elongation of Steel Column Subject to Tension

Based on the stress-strain curve of structural steel, it is known that the steel section can carry more load after yielding point until the fracture point (ultimate load point). This is due to strain hardening phenomena. (Figure 04)

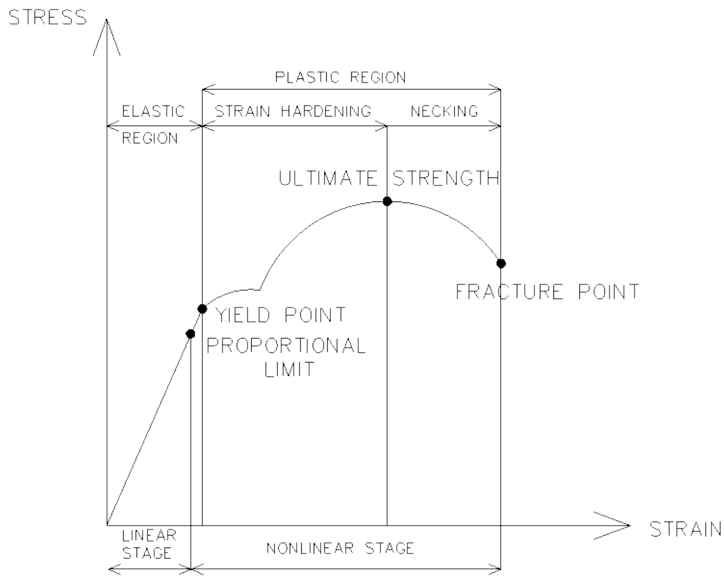

Figure (04). Stress-Strain Curve of Structural Steel

Strain hardening is the stage after the yielding point when yielding occurs. The gross area of the section becomes smaller, and the corresponding elongation occurs in the steel member.

Because of the re-composition of steel atoms, they become closer, as shown in figure (05). Therefore, the reduced yielded section becomes stronger and can carry more load until the ultimate point.

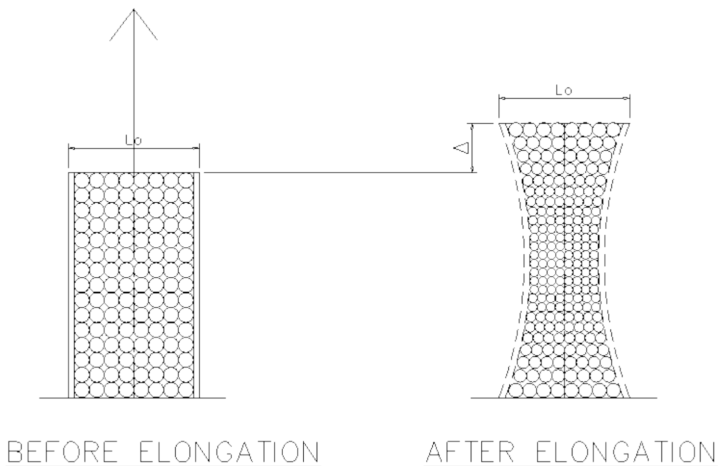

Figure (05). Re-composition of Steel Atoms

<u>Why is the tensile yielding a limit state, despite that the section able to carry more load after the yielding point?</u>

Because of the excessive elongation after yielding, the section is rendered weaker, and less useful. It also affects the strength of the structural system of which the tension member is a part.

b. Tensile Rupture:

$\varphi R_n = \varphi F_u A_e$ $\quad\quad$ $R_n/\Omega = F_u/\Omega\ A_e$ $\quad\quad$ (AISC360-16-Eq.D2-2)

Where;
φ= 0.75 (LRFD)
Ω = 2.00 (ASD)
F_u: Specified minimum tensile strength, ksi (MPa)
$A_e= A_nU$= effective net area, in.^{2}(mm^2), (AISC360-16-Eq.D3-1)
A_n = net area, in.^{2} (mm^2),
U = Shear Lag Factor

For welded connections fully connected by welds; $A_n = A_g$.
For bolted connections; $A_n = A_g – (t_p)*(d_h + 1/16$ in.)

Where;
t_p = thickness of connecting/connected element, in. (mm).
d_h = hole diameter, in. (mm).

For bolted splice plates, $A_e= A_n \leq 0.85A$...

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