# Introduction to Axially Compression Members

**Compression members can be found in:**

1. **Columns**
2. **Top chord of simply supported trusses**
3. **Bracing members**
4. **Parts of members such as the compression flange of rolled beams**

**Compression members can have three different modes of failure**

1. **Flexural buckling (Euler buckling – Global buckling), it depends on the slenderness ratio (KL/r) and end conditions.**
2. **Local buckling occurs when some part of cross section are so thin that can buckle locally in compression before flexural buckling occur.**
3. **Torsional buckling may occur in columns having certain cross sections, where the shear center does not coincide with the center of gravity. These columns failed by twisting or combination of torsion and flexural buckling**

## Euler Formula

**For a pined-pined column with length (L) and cross section (A) and has a moment of Inertia (I) with a modulus of Elastically (E), The buckling load is given by Euler formula ($P_E$)**

$$P_E = \frac{\pi^2 E I}{L^2}$$

**And the buckling stress (critical Stress) , $F_{cr}$ is given by:**

$$F_{cr} = \frac{P_E}{A} = \frac{\pi^2 E (I/A)}{L^2} = \frac{\pi^2 E}{(L/r)^2}$$

**In general, for different end conditions, the buckling length will be equal to KL where K, depends on the end conditions and $F_{cr}$ , is given by**

$$F_{cr} = \frac{\pi^2 E}{(KL/r)^2}$$

**, where KL/r is called slenderness ratio of the column**

Fig k values

## Column Formulas ( Short, Intermediate and long column)

$$\Phi P_n = 0.85\, A_g\, F_{cr}$$

**($\Phi$ = 0.85 for compression members)**

**$A_g$ = gross area of cross section even there are holes for bolts**

**(elastic buckling) , long columns (for $\lambda_c > 1.5$)**

$$F_{cr} = \frac{0.877\, \pi^2 E}{(KL/r)^2} = \frac{0.877}{\lambda_c^2} F_y \qquad \text{where} \quad \lambda_c = \frac{KL/r}{\pi} \sqrt{F_y / E}$$

**( Inelastic buckling), short and intermediate columns**

**For $\lambda_c \le 1.5$** $\qquad F_{cr} = (0.658^{\lambda_c^2})\, F_y$

Curve

## Local buckling of the cross section elements

**Local buckling of flanges and webs of column cross section can occur before the member reaches its buckling load. LRFD specifications provide limiting values for the width-thickness ratios of the individual elements of compression members as follows;**

**Limiting width-thickness ratio for compression elements, local buckling will occur if those limits are exceeded**

**1- Unstiffened elements:**

- **Single angle and double angles**

$$\lambda_r = b/t = 0.45 \sqrt{E / Fy}$$

- **Flanges of W-shapes and channels;**

$$\lambda_r = b/t = 0.56 \sqrt{E / Fy} \quad \text{in pure compression}$$

- **Stem of tees;**

$$\lambda_r = b/t = 0.75 \sqrt{E / Fy}$$

**2- Stiffened elements:**

- **Flanges of rectangular box and hollow structural sections**

$$\lambda_r = b/t = 1.40 \sqrt{E / Fy}$$

- **All other elements uniformly compressed and supported along two edges as web of W-shapes**

$$\lambda_r = b/t = 1.49\sqrt{E / Fy}$$

## Effect of local buckling in the compression strength

**If the limits of b/t > $\lambda_r$, a reduction factor Q is applied to the yield strength, where ;**
**Q = Qs . Qa**

**Qa: reduction factor for stiffened elements as webs**
**Qs : reduction factor for unstiffened elements as angle legs and W-shape flanges**

**Note that ;**

**$Qs = 1.0$ if the cross section is composed of only stiffened elements as hollow sections**

**$Qa = 1.0$ if the cross section is composed of only unstiffened elements as angles and Tees**

**For sections that are composed of both stiffened and unstiffened elements such as W-shapes and channels, $Q = Qs \cdot Qa$**

**For Unstiffened compressed elements**

**a) For single angle**

$$0.446 \sqrt{E / Fy} < b/t < 0.91 \sqrt{E / Fy}$$

$$Qs = 1.34 - 0.76\,(b/t)\sqrt{Fy / E}$$

$$b/t \geq 0.91 \sqrt{E / Fy} \qquad Qs = \frac{0.534\ E}{Fy\ (b/t)^2}$$

**b) For flanges of W-shapes and channels**

$$0.56\sqrt{E / Fy} < b/t < 1.03 \sqrt{E / Fy}$$

$$Qs = 1.415 - 0.74\,(b/t)\sqrt{Fy / E}$$

$$b/t \geq 1.03 \sqrt{E / Fy} \qquad Qs = \frac{0.69\ E}{Fy\ (b/t)^2}$$

**c) For stems in tees**

$$0.75\sqrt{E / Fy} < d/t < 1.03 \sqrt{E / Fy}$$

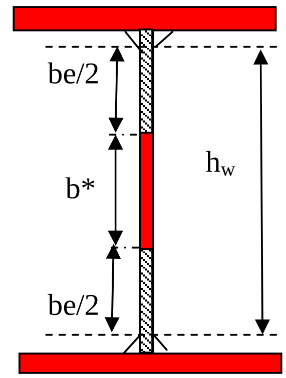
$$Qs = 1.908 - 1.22\,(d/t)\sqrt{Fy / E}$$

$$b/t \geq 1.03 \sqrt{E / Fy} \qquad Qs = \frac{0.69\ E}{Fy\ (d/t)^2}$$

## For Stiffened Compression elements

If $h/t_w \geq 1.49\sqrt{E/Fy}$

$$b_e = 1.91 * t_w * \sqrt{\frac{E}{f}} * \left(1 - \left\{\frac{0.34}{(h/t_w)} * \sqrt{\frac{E}{f}}\right\}\right) < h_w$$




**f : computed elastic compression stress in the stiffened element based on design properties**

$$Qa = \frac{\Sigma Area.effective}{A} = \frac{A - [b^* * t_w]}{A}$$

## Factored Strength of Column

If $\lambda c * \sqrt{Q} < 1.5$ $\quad F_{cr} = Q\,(0.658)^{Q\,\lambda c^2} * Fy$

If $\lambda c * \sqrt{Q} > 1.5$ $\quad F_{cr} = \dfrac{0.877 * Fy}{\lambda c^2}$

where $\lambda_c = \dfrac{KL/r}{\pi}\sqrt{F_y / E}$

$$\Phi P_n = 0.85\ A_g\ F_{cr}$$