Steel Design to Eurocode 3

Compression Members

Columns are vertical members used to carry axial compression loads and due to their slender nature, they are prone to buckling. The behaviour of a column will depend on its slenderness as shown in Figure 1

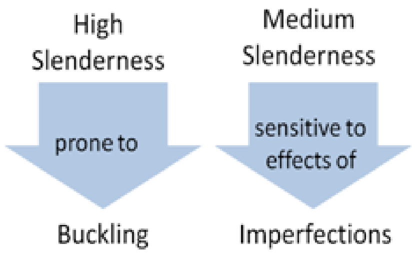

Figure 1 Behaviour of columns is determined by their slenderness

Stocky Columns are not affected by buckling and the strength is related to the material yield stress f_y.

$N_{max} = N_{pl} = A_{eff}\, f_y$

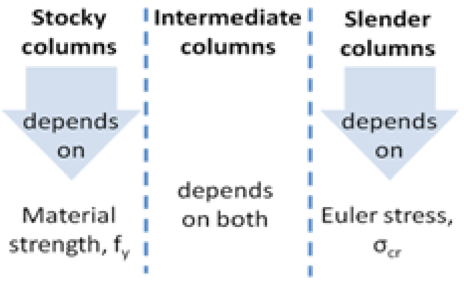

Figure 2: Resistance of columns depends on different factors

Eurocode 3 Approach

To take into account the various imperfections which the Euler formula does not allow for, the Eurocode uses the Perry-Robertson approach. This is approach is the similar to that used in BS 5950.

Table 1 shows the checks required for both slender and stocky columns:

	Slender column $\bar{\lambda} > 0.2$	Stocky Column $\bar{\lambda} < 0.2$
Cross-section Resistance check, $N_{c,Rd}$	✓	✓
Buckling Resistance Check, $N_{b,Rd}$	✓	

Table 1.0 Resistance checks required for slender and stocky columns

Cross-Section Resistance

EN 1993-1-1 Clause 6.2.4 Equation 6.9 states that the design value of the Compression force (N_{Ed}) must be less than the design cross-sectional resistance of the sections to uniform compression force ($N_{c,Rd}$)

$$\frac{N_{Ed}}{N_{c,Rd}} \le 1.0 \qquad (6.9)$$

Cross-section resistance in compression depends on cross-section classification. For Classes 1, 2 and 3:

$$N_{c,Rd} = \frac{A f_y}{\gamma_{M0}} \qquad (6.10)$$

For Class 4 sections:

$$N_{c,Rd} = \frac{A_{eff} f_y}{\gamma_{M0}} \qquad (6.11)$$

$\gamma_{M0} = 1.0$

Cross-section Classification Summary

1. Get f_y from Product Standards
2. Get ε from Table 5.2
3. Substitute the value of ε into the class limits in Table 5.2 to work out the class of the flange and web
4. Take the least favourable class from the flange outstand, web in bending and web in compression results to get the overall section class

For a more detailed description of cross-section classification, please refer to the ‘Cross-section Classification’ handout.

Cross-section Resistance Check Summary

1. Determine the design compression force
2. Choose a section and determine the section classification
3. Determine $N_{c,Rd}$, using equation 6.10 for Class 1,2 and 3 sections, and equation 6.11 for Class 4 sections.
4. Carry out the cross-sectional resistance check by ensuring equation 6.9 is satisfied.

Effective Area A_{eff}

The effective area of the cross-section used for design of compression members with Class 1, 2 or 3 cross-sections, is calculated on the basis of the gross cross-section using the specified dimensions. Holes, if they are used with fasteners in connections, need not be deducted.

Member Buckling Resistance

EN 1993-1-1 Clause 6.3.1 Equation 6.46 states that the design values of the Compression force (N_{Ed}) must be less than the buckling resistance of the compression member ($N_{b,Rd}$)

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1.0 \quad (6.46)$$

Similarly to cross-section resistance, buckling resistance is dependent on the cross-section classification. For sections with Classes 1, 2 and 3:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad (6.47)$$

For Class 4 sections:

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad (6.48)$$

γ_{M1} =1.0

Buckling Curves

Buckling curve selection is dependent on the section geometry. Table 6.2 in EN 1993-1-1 provides guidance on a range of sections.

Effective Buckling Lengths

The effective length of a member will depend on its end conditions. EC3 gives no direct guidance on calculating the buckling length, therefore it is acceptable to use those given in BS 5950 Table 13. Some typical effective lengths are given in Figure 3.

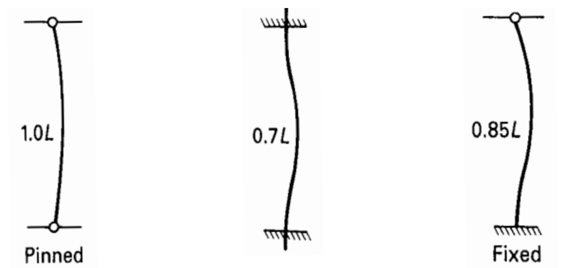

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Figure 3: Effective Lengths for three types of end conditions

Elastic Critical Buckling Load

N_{cr} is the elastic critical buckling load for the relevant buckling mode based on the gross properties of the cross section

$$N_{cr} = \frac{\pi^2 EI}{L^2}$$

Non-dimensional Slenderness $\bar{\lambda}$

For sections with Classes 1, 2 and 3:

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} \quad \text{or} \quad \bar{\lambda} = \frac{L_{cr}}{i}\frac{1}{\lambda_1} \quad (6.50)$$

For Class 4 sections:

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} \quad \text{or} \quad \bar{\lambda} = \frac{L_{cr}}{i}\frac{\sqrt{\frac{A_{eff}}{A}}}{\lambda_1} \quad (6.51)$$

where $\lambda_1 = \pi\sqrt{\frac{E}{f_y}} = 93.9\varepsilon$

Imperfection Factor, α

α is an imperfection factor, first you will need to determine the required buckling curve from Table 6.2 and refer to Table 6.1 to get the value of α:

Buckling Curve	a_0	a	b	c	d
Imperfection Factor	0.13	0.21	0.34	0.49	0.76

EN 1993-1-1 Table 6.1

Reduction Factor, χ

$$\chi = \frac{1}{\phi + (\phi^2 - \bar{\lambda}^2)^{0.5}} \quad (6.49)$$

where $\phi = 0.5\left(1 + \alpha(\bar{\lambda} - 0.2) + \bar{\lambda}^2\right)$

Alternatively, χ may be read from Figure 6.4 in the Eurocodes by using $\bar{\lambda}$ and the required buckling curve.

Buckling Resistance Check Summary

1. Determine the design axial load, N_{Ed}
2. Choose a section and determine the class
3. Calculate the effective length L_{cr}
4. Calculate N_{cr} using the effective length L_{cr}, and E and I which are section properties
5. Calculate $\bar{\lambda}$
6. Determine α by first determining the required buckling curve from Table 6.2 and then reading off the required value of α from Table 6.1.
7. Calculate Φ by substituting in the values of α and $\bar{\lambda}$
8. Calculate χ by substituting in the values of Φ and $\bar{\lambda}$
9. Determine the design buckling resistance of the member by using equation 6.47 or 6.48 and substituting in the value of χ
10. Make sure that the conditions of equation 6.46 are satisfied.