Steel Design to Eurocode 3

Restrained Beams

A beam is considered restrained if:

- The section is bent about its minor axis
- Full lateral restraint is provided
- Closely spaced bracing is provided making the slenderness of the weak axis low
- The compressive flange is restrained again torsion
- The section has a high torsional and lateral bending stiffness

There are a number of factors to consider when designing a beam, and they all must be satisfied for the beam design to be adopted:

- Bending Moment Resistance
- Shear Resistance
- Combined Bending and Shear
- Serviceability

Bending Moment Resistance

In Eurocode 3:

- Clause 6.2 covers the cross-sectional resistance
  - Clause 6.2.5 deals with the cross-sectional resistance for bending.

EN 1993-1-1 Clause 6.2.4 Equation 6.12 states that the design moment (M_{Ed}) must be less than the design cross-sectional moment resistance ($M_{c,Rd}$)

$$\frac{M_{Ed}}{M_{c,Rd}} \leq 1.0 \qquad (6.12)$$

The equation to calculate $M_{c,Rd}$ is dependent on the class of the section. A detailed assessment of cross-section classification can be found in the 'Local Buckling and Cross-Section Classification' handout.

For Class 1 and 2 cross-sections:

$$M_{c,Rd} = M_{pl,Rd} = W_{pl}f_y/\gamma_{M} \qquad (6.13)$$

For Class 3 cross-sections:

$$M_{c,Rd} = M_{el,Rd} = W_{el,min}f_y/ \qquad (6.14)$$

For Class 4 cross sections:

$$M_{c,Rd} = W_{eff,min}f_y/\gamma_{M0} \qquad (6.15)$$

$\gamma_{M0} = 1.0$

Section Modulus, W

Subscripts are used to identify whether or not the section modulus is plastic or elastic and the axis about which it acts.

	BS 5950	EC3
Elastic modulus about the major axis	Z_{xx}	$W_{el,y}$
Elastic modulus about the minor axis	Z_{yy}	$W_{el,z}$
Plastic modulus about the major axis	S_{xx}	$W_{pl,y}$
Plastic modulus about the minor axis	S_{yy}	$W_{pl,z}$

Table 1.0 Section modulus terminology comparison between BS 5950 and EC3

Cross-section Classification Summary

1. Get f_y from Table 3.1
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

Bending Moment Resistance Summary

1. Determine the design moment, M_{Ed}
2. Choose a section and determine the section classification
3. Determine $M_{c,Rd}$, using equation 6.13 for Class 1 and 2 cross-sections, equation 6.14 for Class 3 cross-sections, and equation 6.15 for Class 4 sections. Ensure that the correct value of W, the section modulus is used.
4. Carry out the cross-sectional moment resistance check by ensuring equation 6.12 is satisfied.

Shear Resistance

In Eurocode 3:

- Clause 6.2 covers the cross-sectional resistance
  - Clause 6.2.6 deals with the cross-sectional resistance for shear.

EN 1993-1-1 Clause 6.2.6 Equation 6.17 states that the design shear force (V_{Ed}) must be less than the design plastic shear resistance of the cross-section ($V_{pl,Rd}$)

$$\frac{V_{Ed}}{V_{pl,Rd}} \leq 1.0 \qquad (6.17)$$

$$V_{pl,Rd} = \frac{A_v\left(\frac{f_y}{\sqrt{3}}\right)}{\gamma_{M0}} \quad (6.18)$$

$\gamma_{M0} = 1.0$

Shear Area, A_v

EC3 should provide a slightly larger shear area compared to BS 5950 meaning that the overall resistance will be larger as shown in Figure 1.

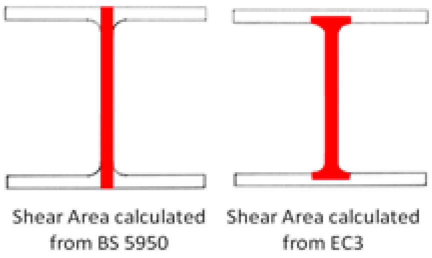

Figure 1: Differences in shear area calculated using BS 5950 and EC3

Type of member	Shear Area, A_v
Rolled I and H sections (load parallel to web)	$A_v = A - 2bt_f + (t_w + 2r)t_f$ but $\geq \eta h_w t_w$
Rolled Channel sections (load parallel to web)	$A_v = A - 2bt_f + (t_w + r)t_f$
Rolled PHS of uniform thickness (load parallel to depth)	$A_v = Ah/(b+h)$
CHS and tubes of uniform thickness	$A_v = 2A/\pi$
Plates and solid bars	$A_v = A$

Table 2.0: Shear area formulas

Term	Definition
A	Cross-sectional area
b	Overall breadth
h	Overall depth
h_w	Depth of web
r	Root radius
t_f	Flange thickness
t_w	Web thickness (taken as the minimum value is the web is not of constant thickness)
η	Constant which may be conservatively taken as 1.0

Table 3.0: Shear area parameter descriptions

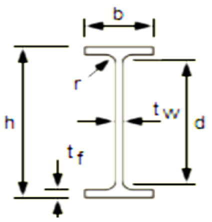

Figure 1: Visual definition of the parameters used in the shear area calculation. (Source: Blue Book)

Shear Resistance Summary

1. Calculate the shear area, Av
2. Substitute the value of Av into equation 6.18 to get the design plastic shear resistance
3. Carry out the cross-sectional plastic shear resistance check by ensuring equation 6.17 is satisfied.

Serviceability

Deflection checks should be made against unfactored permanent actions and unfactored variable actions.

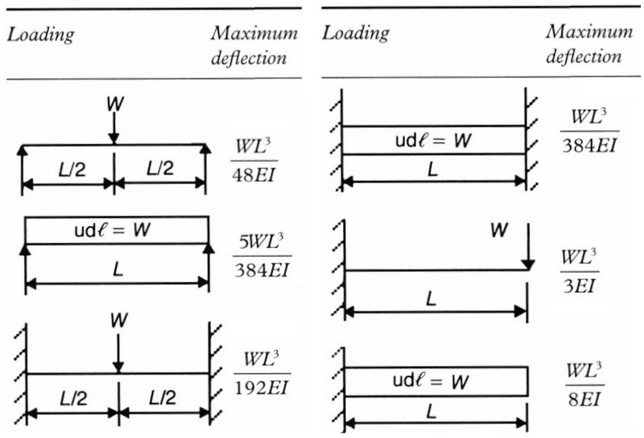

Figure 2: Standard case deflections and corresponding maximum deflection equations

The maximum deflection calculated must not exceed the deflection limit. The deflection limits are not given directly in Eurocode 3, instead, reference must be made to the National Annex.

Design Situation	Deflection limit
Cantilever	Length/180
Beams carrying plaster of other brittle finish	Span/360
Other beams (except purlins and sheeting rails)	Span/200
Purlins and sheeting rails	To suit the characteristics of particular cladding

Table 4.0: Vertical Deflection Limits from NA 2.23 Clause 7.2.1(1) B