The "Blue Book" – quirks, hints and common questions

The Eurocode version of the Blue Book has been around since 2009 and exists in several different guises. David Brown of the SCI comments on the most common questions raised by users.

A long history

The Blue Book (to BS 5950) was first published in 1985 with major revisions associated with amendments to BS 5950 in 1990 and 2000. The familiar presentation of data and resistances was followed as much as possible when the Eurocode version was published in 2009. Minor amendments were made in 2015, correcting an error in the choice of curve for lateral torsion buckling of rectangular hollow sections and a corrigendum to BS EN 1993-1-1. Choosing the wrong curve for RHS was hardly significant – RHS only suffer from LTB at very long lengths if they are tall and narrow, so are almost certainly governed by deflection, not buckling. However it is important that such a widely-used resource, including online versions, is strictly correct. Occasionally, the SCI's Advisory Desk receives questions from structural engineers on values presented in the Blue Book – usually when they are preparing their own resistance calculations and they determine a different result. Often, the message will commence by advising us they have discovered an error. Hopefully, the following guidance will explain some of the commonly reported issues, point out some of the helpful – but rather hidden - features and comment on what with retrospect should have been included.

Reported mistakes

The most commonly reported "mistake" is typically the flexural buckling resistance of a member under axial compression. The "mistake" is that the Blue Book resistance is too low. The same claim is occasionally made about the quoted shear resistance.

The reason for this difference is the use of Table 3.1 of BS EN 1993-1-1 to determine the material strength of the steel. This table has the first reduction in strength when the thickness exceeds 40 mm and again at 80 mm (Figure 1).

Permission to use this table is a nationally determined parameter – and the UK National Annex prohibits its use, insisting that material strengths are taken from the product standard. The product standard retains the stepped reductions at 16, 40, 63, 80 mm etc. Any section which (for example) has a flange between 16 mm and 40 mm would be credited with the higher strength according to Table 3.1 and therefore a higher resistance than allowed by the UK NA. The same issue arises with flanges between 40 mm and 80 mm.

The shear resistance calculation could suffer from exactly the same problem, but is more often linked to the material strength being set by the thickness of the thickest element in a cross section – the flange. If the web is (for example) less than 16 mm, yet the flange is more than 16 mm, the lower design strength is used for the entire cross section. Designers calculating their own resistance can easily miss this subtlety.

The next most commonly reported error is the shear resistance of M12 bolts. The usual comment is that the M12 resistance is too low, at 27.5 kN for property class 8.8 bolts in single shear, although the shear resistances for other diameters are correct. The subtlety here is that M12 bolts are *usually* used in M14 holes. According to Table 11 of BS EN 1090-2, the normal hole for an M12 should be M13, so when the bolt is used in an M14 hole, it is "oversize". Then the requirements of BS EN 1993–1–8 clause 3.6.1(5) apply, which says that M12 bolts may be used in M14 holes, but a factor of 0.85 should be applied to the calculated shear resistance.

Thus the calculated resistance for an M12, property class 8.8 bolt becomes:

$$F_{\mathrm{v,Rd}} = \frac{\alpha_{\mathrm{v}} f_{\mathrm{ub}} A}{\gamma_{\mathrm{M2}}} \times 0.85 = \frac{0.6 \times 800 \times 84.3}{1.25 \times 100} \times 0.85 = 27.5 \text{ kN as quoted}$$

The same issue would apply to M14 bolts, but these are not a common diameter and therefore not covered in the Blue Book.

Lateral torsional buckling resistances

LTB resistances appear in two locations in the Blue Book. They appear in tables for LTB resistance alone, and again in the tables for combined axial load and bending. Correspondents sometimes point out that the values are different.

In fact the values are identical – for $C_1 = 1$, which represents a uniform bending moment. Rather regrettably perhaps, the combined axial load and bending tables only have room for single lines of LTB resistances, so the most conservative values had to be chosen, which is for $C_1 = 1$. The tables for LTB

▶ 38

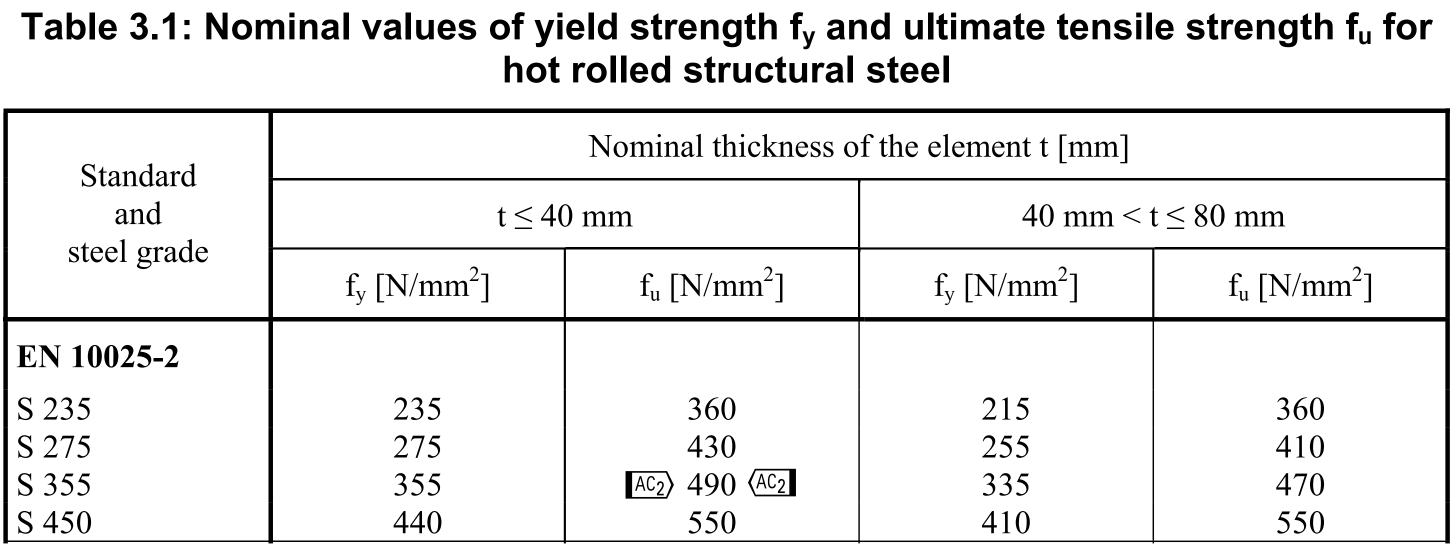


Table 3.1: Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

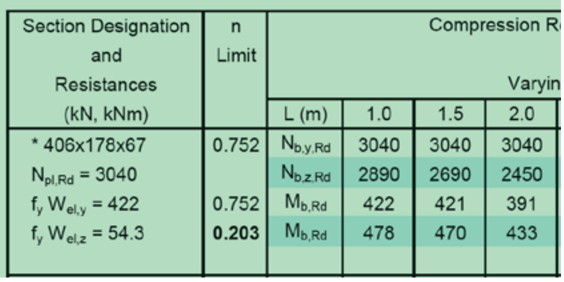
Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm^2]	f_u [N/mm^2]	f_y [N/mm^2]	f_u [N/mm^2]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	AC2 490 AC2	335	470
S 450	440	550	410	550

Figure 1: Extract from Table 3.1 from BS EN 1993-1-1

▶ 36

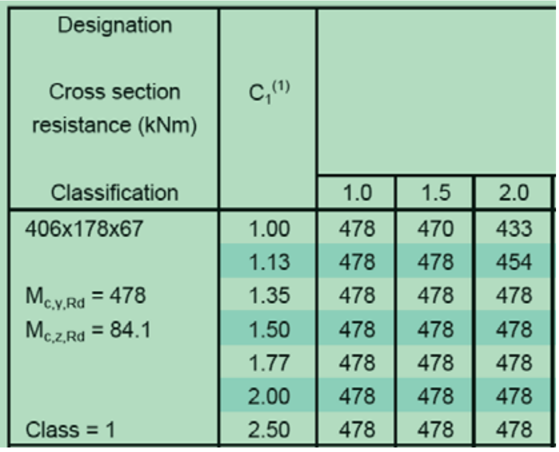
alone have values for seven different values of C_1, covering standard cases such as a UDL on a pin-ended beam, and providing additional values to aid interpolation.

The situation becomes more complicated, since the combined axial load and bending tables have two rows for the LTB resistance, as shown in Figure 2. Both rows are indicated as $M_{b,Rd}$.



Section Designation and Resistances (kN, kNm)	n Limit	Compression R			
					Varyin
		L (m)	1.0	1.5	2.0
* 406x178x67	0.752	$N_{b,y,Rd}$	3040	3040	3040
$N_{pl,Rd}$ = 3040		$N_{b,z,Rd}$	2890	2690	2450
$f_y W_{el,y}$ = 422	0.752	$M_{b,Rd}$	422	421	391
$f_y W_{el,z}$ = 54.3	0.203	$M_{b,Rd}$	478	470	433

Combined axial load and bending



Designation Cross section resistance (kNm) Classification	$C_1^{(1)}$	1.0	1.5	2.0
406x178x67	1.00	478	470	433
	1.13	478	478	454
$M_{c,y,Rd}$ = 478	1.35	478	478	478
$M_{c,z,Rd}$ = 84.1	1.50	478	478	478
	1.77	478	478	478
	2.00	478	478	478
Class = 1	2.50	478	478	478

LTB alone

Figure 2: Extract from the combined axial load and bending tables, and the complementary LTB tables

The lower row is for Class 1 and Class 2 sections. For these sections the plastic modulus, W_{pl} is used in the calculation. The upper row is for Class 3 sections, which use the elastic modulus W_{el} and thus a different resistance is computed. A section which was Class 1 or Class 2 can become Class 3 (and indeed Class 4) under increasing levels of axial load, so both LTB resistances had to be presented.

In contrast, all Universal Beams are Class 1 under bending alone, so the LTB tables show the resistance based on the plastic modulus.

The best advice is: If the section is Class 1 or Class 2, take the LTB resistances from the LTB tables using the appropriate value of C_1. If the section is Class 3, the LTB resistances from the combined axial load and bending tables are conservative. An improved resistance for Class 3 sections could be calculated separately if the C_1 value was much higher than 1.0.

The reasoning for the two rows only of LTB resistances in the combined tables really flows from the BS 5950 presentation. In BS 5950, the effect of a varying bending moment diagram was accounted for in the m_{LT} factor, but this was applied after calculating the resistance M_b (see clause 4.3.6.2 of BS 5950). Thus there was only a requirement to present M_b for the two classes of section in only two rows, leaving the designer to apply the m_{LT} factor.

Quick – what Class is the section?

The long-winded way to determine the section Class when a member is subject to combined axial load and bending is to classify the section using Table 5.2 of BS EN 1993-1-1, calculating the values of α and ψ, checking $^c/_t$ against the limits within the table.

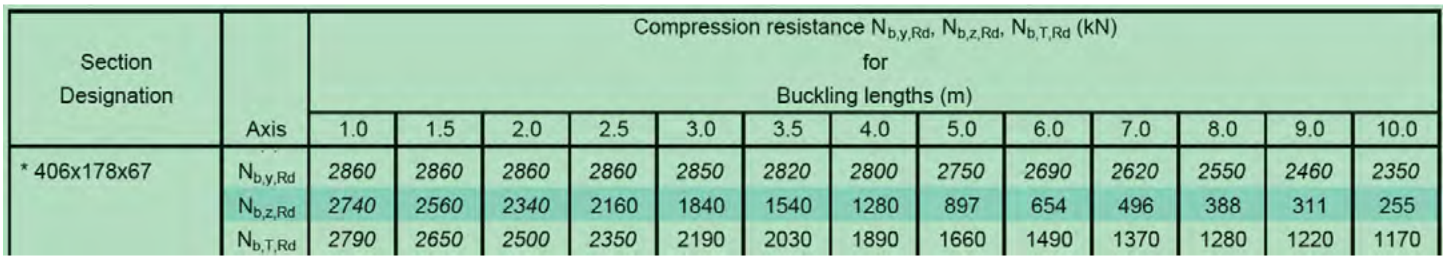
The much easier way is to use the "n" limits already seen in Figure 2. The "n" limit is a proportion of the cross-sectional resistance, here given as $N_{pl,Rd}$ and indicates the axial load when a section becomes Class 2, and the axial load when a section becomes Class 3.

For the example shown in Figure 2:

0.203 × 3040 = 617 kN Thus at axial loads lower than 617 kN, the section is "at least" Class 2.

0.752 × 3040 = 2286 kN Thus for loads greater than 617 kN and less than 2286 kN, the section is Class 3. At axial loads greater than 2286 kN, the section becomes Class 4.

The reason for the "at least" in the above definition should become clear in Table 1. For Class 1 and Class 2 sections, the same section properties are used in both the calculation of the axial resistance and the bending resistance.



Section Designation	Axis	Compression resistance $N_{b,y,Rd}$, $N_{b,z,Rd}$, $N_{b,T,Rd}$ (kN) for Buckling lengths (m)												
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0
* 406x178x67	$N_{b,y,Rd}$	*2860*	*2860*	*2860*	*2860*	*2850*	*2820*	*2800*	*2750*	*2690*	*2620*	*2550*	*2460*	*2350*
	$N_{b,z,Rd}$	*2740*	*2560*	*2340*	2160	1840	1540	1280	897	654	496	388	311	255
	$N_{b,T,Rd}$	*2790*	*2650*	*2500*	*2350*	2190	2030	1890	1660	1490	1370	1280	1220	1170

Figure 3: Axial resistances from the compression (alone) tables

It therefore does not matter - to know the section is "at least" Class 2 is sufficient.

Table 1. Section properties required for resistance calculations.

	Section property required	
Section Class	Axial resistance	Bending resistance
Class 1	A	W_{pl}
Class 2	A	W_{pl}
Class 3	A	W_{el}
Class 4	A_{eff}	W_{eff}

The axial resistances are different?

Another subtle difference that gives rise to some questions is seen when comparing the axial resistances in Figure 2, (from the combined axial load and bending tables) with the complementary axial resistances in Figure 3, which is taken from the tables for axial load alone.

In Figure 3, the axial resistances are lower, and some are in italic font. Here the explanation is straightforward and given at the bottom of the tables. Italic font indicates the section is Class 4, and as seen in Table 1, the effective area is used in the calculation of the resistance. Inspection of the full tables shows that the values are identical when not Class 4 (not in italic font). The more onerous classification which affects the "compression alone" tables is for that precise reason – the entire cross section is in compression and the web becomes Class 4. As soon as a hint of bending is introduced, the web is not all in compression and is less enthusiastic to buckle. A more scientific explanation can be seen by appreciating that the relevant column in Table 5.2 of BS EN 1993-1-1 moves from "Part subject to bending" to "Part subject to bending and compression" and the limiting values are more generous.

What could have been better?

A matter of regret is a small but important feature of the tables covering bolt resistances in tension. In BS 5950, two values of bolt tension resistance were defined. One value was the "full" resistance. If this value was used, described as the "Exact" capacity in the BS 5950 Blue Book, prying (which increases the force in the bolt) had to be taken into account. The second value, described as the "Nominal" capacity could be used if certain geometric limits were observed. When using the "Nominal" capacity, prying could be neglected, as only 80% of the "Exact" capacity was used.

In the Eurocode Blue Book, only the equivalent of the "Exact" value is presented, leaving designers to include prying in their calculations. Some years after the Blue Book was prepared, AD 354 was published, which offered exactly the same options as BS 5950. The current danger is that designers neglect prying, but take the published values as the "Nominal" resistances. With the benefit of hindsight, an additional column of resistances, being 80% of those currently presented, would have been very helpful. Perhaps designers might mark up their own copies! ■