The new Blue Book

The new "Blue Book" of member resistances to EC3 is nearing completion. David Brown, Deputy Director of SCI introduces some of the significant features.

The "Blue Book" is known throughout the steel world, and the instantly recognisable, (and usually well-thumbed) publication is found on the desks of many designers. The Blue Book is about to be made available after a full Eurocode makeover, and this article describes some of the significant comparisons between the versions to BS 5950 and EC3.

Eurocode resistances, but for UK use only!

The original idea that a Eurocode would represent an absolutely common standard across the whole of Europe became watered down somewhere along the 30 year development programme. Now, limited national choice is available over certain aspects of the Eurocode – and these are described in the National Annex to each Eurocode Part. The relevant National Annex is the one for the country where the structure is to be constructed, so the UK National Annexes must be used for structures to be built in the UK. Thus, the Eurocode Blue Book will be appropriate for UK structures, but not necessarily in any other countries.

This same problem applies to other publications – that slightly different versions could exist for use in different countries. An emblem has been developed for the suite of publications that indicates their scope – the ring of stars indicates that it's a Eurocode guide, and the "UK" indicates that the guide adopts the UK National Annex values.

Section Properties

The values have not changed (other than possibly the display of significant figures), but the nomenclature certainly has. Member axis, major dimensions and section properties all adopt the Eurocode terms, and are shown in the new Blue Book.

Major changes are shownat the top of the next column. Some have a sound logic – modulii are always *W* for example, and issues connected with stiffness are always *I*. The importance of the subscripts becomes clear, as these define the particular property, for example whether the modulus is elastic or plastic.

BS5950	EC3	BS5950	EC3	BS5950	EC3
A	A	P	N	p_y	f_y
Z	W_{el}	M_x	M_y	p_b	
S	W_{pl}	V	V	p_c	
I_x	I_y	H	I_w	r	i
I_y	I_z	J	I_t		

Flexural Buckling

Figure 1 shows part of the table for UKC resistances. It looks mostly familiar, with resistances for the major axis ($N_{b,y,Rd}$) and the minor axis ($N_{b,z,Rd}$) presented for different buckling lengths. A third row is presented for Beams, Columns and Channels which provides the resistance to torsional buckling, $N_{b,T,Rd}$. An article which explains torsional buckling, with illustrations of the phenomena, was published in *New Steel Construction* in April 2006. Torsional buckling of beam and column sections will only be critical if the flanges are not equally restrained in the minor axis; in most cases, torsional buckling will not be the critical mode.

Section Designation	Axis	Compression resistance $N_{b,y,Rd}$, $N_{b,z,Rd}$, $N_{b,T,Rd}$ (kN) for Buckling lengths L_{cr} (m)						
		1.0	1.5	2.0	2.5	3.0	3.5	4.0
203x203x127 +	$N_{b,y,Rd}$	5590	5590	5460	5320	5180	5030	487[illegible]
	$N_{b,z,Rd}$	5490	5160	4810	4430	4040	3630	3220
	$N_{b,T,Rd}$	5540	5340	5210	5120	5060	5020	4980
203x203x113 +	$N_{b,y,Rd}$	5000	5000	4880	4760	4630	4490	434[illegible]
	$N_{b,z,Rd}$	4910	4610	4290	3950	3590	3220	2860
	$N_{b,T,Rd}$	4940	4750	4610	4520	4450	4400	4370
203x203x100 +	$N_{b,y,Rd}$	4380	4370	4270	4160	4040	3920	3780
	$N_{b,z,Rd}$	4290	4030	3750	3450	3130	2800	248[illegible]
	$N_{b,T,Rd}$	4310	4130	3990	3890	3820	3770	37[illegible]
203x203x86	$N_{b,y,Rd}$	3800	3780	3690	3590	3490	3380	[illegible]
	N[illegible]	371[illegible]	3480	[illegible]230	2970	2690	[illegible]	

Figure 1: UKC compression resistances, S355, from the new Blue Book

Table 1 shows a comparison for some typical members, to BS 5950 and EC3

Member	Grade	Length (m)	Minimum Resistance (kN) BS 5950	Minimum Resistance (kN) EC3
203 UKC 60	S355	6	862	844
203 × 133 × 30 UKB	S355	5	272	268
114 × 5 CHS	S355	6	133	132
150 × 150 × 5 SHS	S355	4	794	756

Table 1: Comparison of resistances to flexural buckling

The technical reason for these modest differences is that the Eurocode has a slightly shorter plateau in the strut buckling curves than BS 5950, and the curves themselves are slightly different (those

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interested can compare values between Clause 6.6.1.2 in BS EN 1993-1-1 and Annex C of BS 5950). At larger values of slenderness, the values are very close, as expected.

Elliptical hollow sections

For the first time, the new Blue Book includes resistances for elliptical hollow sections. Although section properties have been provided in previous publications, there had been insufficient development to allow resistances to be prepared. Following work at Imperial College, resistances in compression, bending and shear have been provided.

In some cases, particularly in combined bending and compression, the resistances for elliptical hollow sections will be conservative. This is because the section has been classified on the basis of the compression alone, and this (sometimes more onerous) classification has been used when calculating the bending resistance.

If an elliptical section is found to be class 4, two options are possible:

- Calculate the resistance based on an effective area, or
- Calculate the resistance based on the full area, but using a reduced design strength so that the section remains Class 3.

In compression alone, the resistances are based on the higher result from either approach. In combined bending and axial compression, only the second approach is used, and furthermore, the same reduced design strength and elastic modulus is used when calculating the bending resistance.

Lateral-torsional buckling

Figure 2 shows part of the table for UKB resistances. Although the resistances are tabulated against lengths, the resistances also depend on the C_1 factor, shown in the second column. In fact, the Eurocode does not mention C_1 at all, but simply defines that the resistance is based on slenderness, and in turn the slenderness depends on the elastic critical buckling resistance, M_{cr}. No expressions are offered in the Eurocode for the calculation of M_{cr}. The value can be calculated using software, or by expressions found in various sources of non-conflicting complementary information (NCCI). The value of M_{cr} depends on the shape of the bending moment, as can be seen in the expression for non-destabilising loads (taken from Access Steel):

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}}$$

The C_1 factor accounts for the shape of the bending moment diagram, allowing for the fact that a uniform bending moment diagram is the most onerous situation – anything else is less onerous. The same physics is allowed for in BS 5950 by the use of the equivalent uniform moment factor m_{LT} from Table 18.

In BS 5950, the calculation of m_{LT} is independent of the calculation of the lateral torsional buckling resistance, M_b and so only one row of resistances needed to be shown for each steel section. In the Eurocode approach, the lateral torsional buckling resistance incorporates the effect of a non-uniform bending moment within the calculation, and so resistances for various shapes of bending moment diagram (manifest as different values of C_1) are provided.

Some designers will recall the 1990 version of BS 5950, where non-uniform bending moments were dealt with by the equivalent uniform moment factor *m* or by the slenderness correction factor *n*. Whereas *m* was independent of the calculation of M_b, the influence of *n* was included in the calculation. The complementary Blue Book at the time (the fourth edition) had to show resistances for various *n* factors, rather like the Eurocode version.

Table 2 shows the differences in the codes.

	BS 5950:1990	BS 5950:2000	EC3
Basic equation	$M = mM_A$	$M_x \le M_b / m_{LT}$	$\frac{M_{ed}}{M_{b.Rd}} \le 1.0$
Approach	using *m* or *n* (M_A depends on *n*)	using m_{LT}	using C_1 $M_{b,Rd}$ depends on C_1
Blue Book	Rows required for values of *n*	Single value of M_b	Rows required for values of C_1

Table 2: Approach to non-uniform bending moments

The C_1 factors can be found from Access Steel at *http://www.access-steel.com* Typical cases are shown in Table 3.

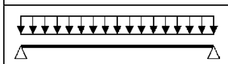
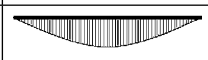
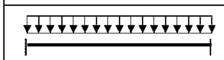
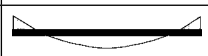
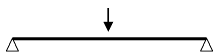
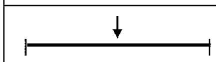
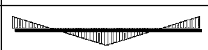
Loading and support conditions	Bending moment diagram	C1
		1.127
		2.578
		1.348
		1.683

Table 3: Typical values of factor C_1

The lateral torsional buckling resistances are generally increased (often significantly so) compared to BS 5950, as the following example demonstrates.

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Designation Cross section resistance (kNm) Classification	C_1 (1)	Buckling Resistance Moment $M_{b,Rd}$ (kNm) for Length between lateral restraints, L (m)													Second Moment of Area y-y axis I_y cm^4
		2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
533x210x101	1.00	856	735	617	513	429	366	317	279	249	225	204	185	169	61500
	1.50	901	880	784	685	592	510	442	386	342	311	286	265	246	
$M_{c,y,Rd}$ = 901	2.00	901	901	894	812	726	644	569	504	448	400	359	331	309	
$M_{c,z,Rd}$ = 138	2.50	901	901	901	901	829	754	681	614	553	500	452	411	374	
Class = 1	2.75	901	901	901	901	872	801	730	664	603	547	498	454	415	
533x210x92	1.00	790	672	557	456	378	319	274	240	213	190	170	154	140	55200
	1.50	838	809	714	615	524	445	381	329	294	266	244	225	208	
$M_{c,y,Rd}$ = 838	2.00	838	838	820	736	649	567	494	432	379	335	305	282	263	
$M_{c,z,Rd}$ = 126	2.50	838	838	838	824	748	671	597	531	473	422	377	339	312	
Class = 1	2.75	838	838	838	838	789	715	644	577	517	464	418	377	341	
533x210x82	1.00	684	577	[illegible]	381	312	260	222	193	170	149	132	119	109	47500

Figure 2: UKB bending resistances, S355, from the new Blue Book

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Assuming a 7m pin-ended beam, S355, with a UDL.
According to BS 5950, the resistance of a 533 × 210 × 92 UKB is 262 kNm
(taken from the 7th edition blue book).
From Table 18, m_{LT} is 0.925.
Thus the maximum applied moment is 262/0.925 = 283 kNm

For a UDL, C_1 is 1.127
From Figure 2, the resistance is 319 kNm when C_1 = 1
445 kNm when C_1 = 1.5
Interpolating, when C_1 = 1.127, the resistance is 351 kNm

This is some 24% greater than the BS 5950 resistance.

Conclusions

This article has looked at the new Blue Book, expected soon, and what are possibly the two most used tables – compression and bending. The compression resistances are as simple to use as they always have been, with very similar results. The lateral-torsional buckling tables generally demonstrate the very significant advantage of using the Eurocode, with increased resistances. The requirement for a C_1 factor may be a complication (the use of C_1 = 1.0 is conservative), but is not very onerous. If there is sufficient demand, it is possible to make tables available at the "standard" C_1 values, for example with C_1 = 1.127 for the common case of a UDL on a pin-ended beam.

In addition to the Blue Book, a new Red Book will be available, as well as an on-line version. All three should be available soon after the National Annex is published by BSI.

Future articles will look at other tables, including those for combined bending and compression.