AD 387
Elastic critical moment and correction factor *g* for bi-symmetric I sections

Some SCI members have recently been asking questions about the variety of expressions available to calculate the elastic critical moment, M_{cr}. For some reason, members have been enquiring about the use of the correction factor, g, which appears in expressions provided in certain resources and is omitted in others.

This advisory desk note provides guidance/clarification on M_{cr} and g.

The most general expression, for bi-symmetric I section is given in various resources, including SN002[1], as:

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{(kL)^2 g}\left(\sqrt{\left(\frac{k}{k_w}\right)^2 \frac{I_w}{I_z} + \frac{(kL)^2 GI_t}{\pi^2 EI_z} + (C_2 z_g)^2} - C_2 z_g\right)$$

Of interest in this Advisory Desk note is the correction factor, g, which appears in the first part of the expression.

Correction factor g allows for initial in-plane curvature of the beam. The value of g is given by:

$g = \sqrt{\left(1 - \frac{I_z}{I_y}\right)}$, or g may conservatively be taken as 1.0.

In many resources therefore, g is taken as 1.0 and simply disappears from the expression for M_{cr}. Thus for the simple case of fork end supports and loads which are not destabilising, the familiar expression for M_{cr} results:

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

Simplified expressions to determine the non-dimensional slenderness directly, without calculating M_{cr}, are also available. In SN002, a simplified expression is given as $\bar{\lambda}_{LT} = \frac{1}{\sqrt{C_1}} UV\bar{\lambda}_z \sqrt{\beta_w}$. Readers will recognise this as the form of the expression in BS 5950-1, Clause B.2.3 given as $\lambda_{LT} = uv\lambda\sqrt{\beta_w}$

In SN002, U is defined as $U = \sqrt{\frac{W_{pl,y}\,g}{A}\sqrt{\frac{I_z}{I_w}}}$, which includes the influence of the correction factor, g.

In BS 5950-1, u is given in B.2.3 as $u = \left(\frac{4S_x^2\gamma}{A^2 h_s^2}\right)^{0.25}$

Although g may not be immediately apparent, the effect is seen in the variable, γ, which is defined as $\gamma = (1 - I_y/I_x)$

Impact of including the correction factor

For universal beams, g varies between 0.931 and 0.989. For universal columns, g varies between 0.780 and 0.829.

Of course, the lateral torsional buckling resistance moment, $M_{b,Rd,}$ does not vary directly in proportion to the correction factor g. The effect is illustrated in the following example.

533 × 210 × 82 UKB, and 203 UKC 46, both S355, 6 m buckling length, $C_1 = 1$.

Calculation approach	**533 UKB**		**203 UKC**	
	M_{cr} (kNm)	$M_{b,Rd}$ (kNm)	M_{cr} (kNm)	$M_{b,Rd}$ (kNm)
Simple approach with $UV = 0.9$ (actually, $UV = 0.775$)		254.8		85.4
Simple approach with U and V calculated, but no correction factor, g		312.4		115.3
Simple approach with U and V calculated, including correction factor, g		320.1		125.2
Calculating M_{cr}, but no correction factor, g	369.4	311.8	152.8	115.4
Blue Book [2]		312.0		115.0
Calculating M_{cr}, with correction factor, g	377.5	316.5	187.9	126.8
LTBeam [3]	370.3		152.9	

The impact of g varies as the slenderness changes, so the results in the table above should not be taken as representing the general situation. For the universal beam, the increase in resistance is only 1.2%. Although for the universal column section, the increase is larger (10.4%), universal columns used as beams are not often likely to have lateral torsional buckling as the critical check. The table above also indicates the conservatism in simply assuming that $UV = 0.9$.

SCI recommend that for simplicity and safety, g is taken as 1.0. It would be unsafe to include the effect of g if the beam were pre-cambered [4]. In the Blue Book, $M_{b,Rd}$ is calculated by firstly determining M_{cr}, and g is taken as 1.0.

References:

[1] NCCI: Determination of non dimensional slenderness of I and H sections, 2006 (available via www.steelbiz.org).

[2] SCI P363, Steel Building Design: Design Data updated May 2013.

[3] LTBeam (software freely downable from www.cticm.com).

[4] Kirby, P.A. and Nethercot, D.A. Design for structural stability, Constrado Monographs, 1979.

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