$$M_c = 1.11 M_y \left(1 - \frac{10 M_y}{36 M_o} \right) \quad \text{for } 2.78\, M_y > M_o > 0.56\, M_y \qquad (5.23)$$

$$M_c = M_o \quad \text{for } M_o \leq 0.56\, M_y \qquad (5.24)$$

They are included for all cases in AS/NZS 4600:2005 as Eqs (3.3.3.2(3))-(5). They have been confirmed by research on purlins in Ref. 5.7 and on beam-columns in Refs 5.8 and 5.9. They are compared with the former equations in AS/NZS 4600:1996 Clause 3.3.3.2(b) in Fig. 5.8. It can be seen that the 2005 equations are significantly above the 1996 equations for beam non-dimensional slenderness values greater than approximately 1.0. The Eurocode 3 Part 1.3 (Ref. 1.20) beam design curve is also shown in Fig. 5.8 for comparison.

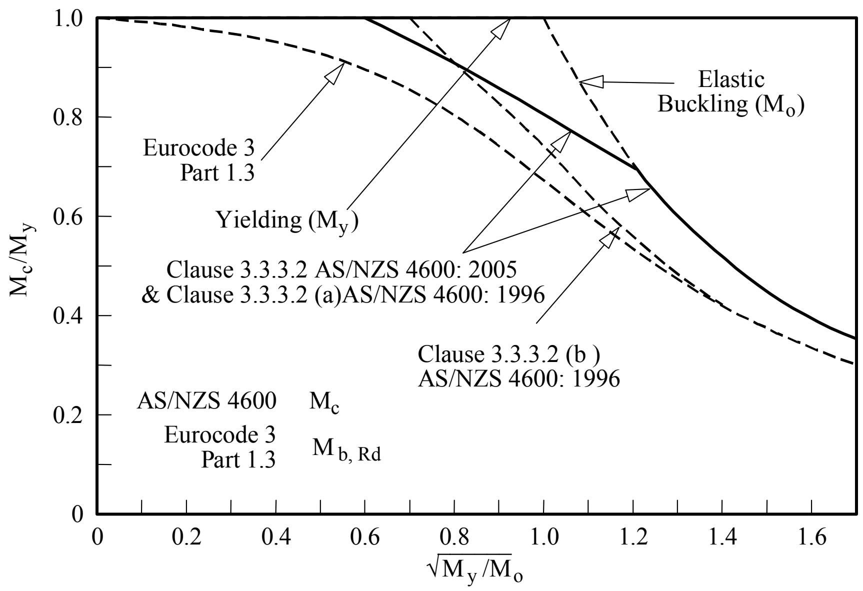

Fig. 5.8 Comparison of beam design curves

A detailed discussion of the lateral buckling strengths of unsheeted cold-formed beams is given in Ref. 5.10.

5.3 Distortional Buckling

5.3.1 Flange Distortional Buckling

5.3.1.1 <u>Compression Members</u>

Distortional buckling of compression members such as C-sections usually involves rotation of each flange and lip about the flange-web junction in opposite directions as shown in Fig. 1.18(a). This mode is often called 'flange distortional buckling'. The web undergoes flexure at the same half-wavelength as the flange buckle, and the whole section may translate slightly in a direction normal to the web also at the same half-wavelength as the flange and web buckling deformation. Distortional buckling in this mode has been investigated in detail by Hancock (Ref. 5.11) mainly for sections used in steel storage racks, by Lau and Hancock (Refs 5.12, 5.13, 5.14) for a range of different C- and rack sections, and by Kwon and Hancock (Refs 5.15, 5.16) for high strength steel channel sections with intermediate stiffeners.

The elastic distortional buckling stress (f_{od}) is based on the flexural-torsional buckling of a simple flange model developed by Lau and Hancock (Ref. 5.17) as shown in Fig. 5.9(a). The rotational spring (k_φ) represents the flexural restraint provided by the web which is in pure compression, and the translational spring (k_x) represents the resistance to translational movement of the section in the buckling mode. As a result of the compressive stress in the web, the model includes a reduction in the flexural restraint provided by the web. The model as derived is not limited to simple flange-lip combinations but may involve complex lips with sloping stiffeners and/or return lips. In the Lau and Hancock model, it is assumed that the value of the translational spring stiffness (k_x) is zero so that the flange was free to translate in the x-direction in the buckling mode. The equation for the rotational spring stiffness (k_φ) is given by

$$k_\varphi = \frac{Et^3}{5.46\,(b_w + 0.06\,\lambda)}\left[1 - \frac{1.11\,f'_{od}}{Et^2}\left(\frac{b_w^2\lambda}{b_w^2+\lambda^2}\right)^2\right] \quad (5.25)$$

where b_w is the web depth. In Eq. (5.25), λ is the half-wavelength of the distortional buckle given by:

$$\lambda = 4.80\left(\frac{I_{xf}\, b_f^2\, b_w}{t^3}\right)^{0.25} \quad (5.26)$$

where I_{xf} is the second moment of area of the flange and lip about the x-axis in Fig. 5.9(a). The spring restraint (k_φ) assumes the web is bent symmetrically as shown in Fig. 5.9(b). The term (f'_{od}) is the compressive stress in the web at distortional buckling, computed assuming k_φ is zero. The computation process is iterative due to the incorporation of f'_{od} in Eq. (5.25), but only one iteration is required. These formulations are included in Appendices D1 and D2 of AS/NZS 4600.

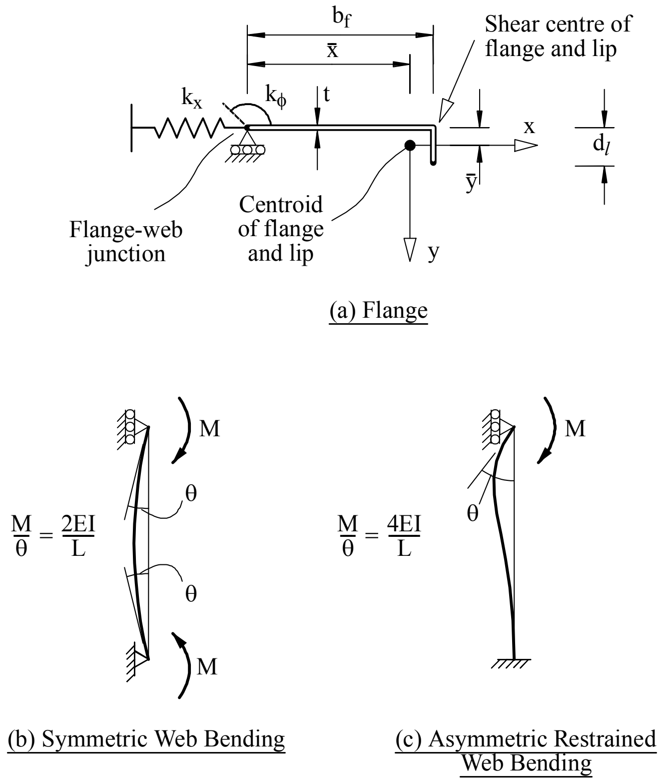

Fig. 5.9 Flange distortional buckling model

Strength design curves were derived from test data in Kwon and Hancock (Ref. 5.16) and summarised in Hancock et al. (Ref. 5.18). They are described in detail in Chapter 7 of this book.

5.3.1.2 Flexural Members

Flange distortional buckling of flexural members such as C- and Z-sections usually involves rotation of only the compression flange and lip about the flange-web junction as shown in Fig. 1.18(b). The web undergoes flexure at the same half-wavelength as the flange buckle, and the compression flange may translate slightly in a direction normal to the web, also at the same half-wavelength as the flange and web buckling deformations. The web buckle involves double curvature transverse bending of the web as described in Hancock (Ref 5.19). A graph of buckling stress versus buckle half-wavelength is shown in Fig. 3.12. In this figure, it can be seen that the buckling stress for the short half-wavelength flange distortional buckling is significantly less than that for the longer half-wavelength lateral distortional buckling with transverse web bending when the tension flange of the C-section is restrained to prevent flexural-torsional buckling.

As for the compression member, the elastic distortional buckling stress (f_{od}) for flange distortional buckling is based on the flexural-torsional buckling of a simple flange model as shown in Fig. 5.9(a). The rotational spring (k_φ) represents the flexural restraint provided by the web which is in bending, and the translational spring (k_x) represents the resistance to translational movement of the section in the buckling mode. As a result of the compressive stress in the web resulting from bending, the model includes a reduction in the flexural restraint provided by the web. This reduction is different from that for the compression member given by Eq. (5.25). The equation for the rotational spring stiffness (k_φ) is given by:

$$k_\varphi = \left[\frac{2Et^3}{5.46\left(b_w + 0.06\lambda\right)}\right] \times \left[1 - \frac{1.11 f'_{od}}{Et^2}\left(\frac{b_w^4 \lambda^2}{12.56\lambda^4 + 2.192 b_w^4 + 13.39\lambda^2 b_w^2}\right)\right] \quad (5.27)$$

where the symbols are the same as for Eq. (5.25). In Eq. (5.27), λ is the half-wavelength of the distortional buckle given by:

$$\lambda = 4.80\left(\frac{I_{xf}\, b_f^2\, b_w}{2t^3}\right)^{0.25} \quad (5.28)$$

where I_{xf} is the second moment of area of the flange and lip about the x-axis in Fig. 5.9(a).

The spring restraint (k_φ) assumes the web is bent asymmetrically as shown in Fig. 5.9(c).

As for compression, the term f'_{od} is the compressive stress in the web at distortional buckling, computed assuming k_φ is zero. The computation process is iterative due to the incorporation of f'_{od} in Eq. (5.27) but only one iteration is required. These formulations have been included in Appendix D3 of AS/NZS 4600.

Strength design curves were calibrated against test data in Hancock, Rogers and Schuster (Ref. 5.20). They have been included as Clause 3.3.3.3(a) of AS/NZS 4600. They are not the same as for compression members since it appears that the strength in bending is slightly higher than in compression.

Design of Cold-Formed Steel Structures

(To Australian/New Zealand Standard

AS/NZS 4600:2005)

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