CHAPTER 5 BEAMS, PURLINS AND BRACING

5.1 General

The design of beams for strength is usually governed by one of the following limit states:

(a) yielding of the most heavily loaded cross section in bending including local and post-local buckling of the thin plates forming the cross-section, or

(b) elastic or inelastic buckling of the whole beam in a flexural-torsional (commonly called lateral) mode, or

(c) elastic or inelastic buckling of a length of beam in a distortional mode, or

(d) yielding and/or buckling of the web subjected to shear, or combined shear and bending, or

(e) yielding and/or buckling of the web subjected to bearing (web crippling) or combined bearing and bending.

The design for (a) determines the nominal section moment capacity (M_s) given by Eq. (5.1).

$$M_s = Z_e f_y \tag{5.1}$$

where Z_e is the effective section modulus about a given axis computed at the yield stress (f_y). Calculation of the effective section modulus at yield is described in Chapter 4 of this book. As specified in Table 1.6 of AS/NZS 4600, the capacity reduction factor (φ_b) for computing the design section moment capacity is 0.95 for sections with stiffened or partially stiffened compression flanges and 0.90 for sections with unstiffened compression flanges.

The design for (b) and (c) determines the nominal member moment capacity (M_b) given by Eq. (5.2).

$$M_b = Z_c f_c \tag{5.2}$$

where

$$f_c = \frac{M_c}{Z_f} \tag{5.3}$$

Mc is the critical moment for lateral or distortional buckling. Zc is the effective section modulus for the extreme compression fibre computed at the critical stress (fc) and Zf is the full unreduced section modulus for the extreme compression fibre. Equation 5.2 allows for the interaction effect of local buckling on lateral or distortional buckling. The use of the effective section modulus computed at the critical stress (fc) rather than the yield stress (fy) allows for the fact that the section may not be fully stressed when the critical moment is reached and hence the effective section modulus is not reduced to its value at yield. The method is called the unified approach and is described in detail in Ref. 4.10. For the specific case of distortional buckling where the flange locally buckles before the web, interaction buckling does not occur and the full section modulus (Zf) is used in place of the effective section modulus (Zc) as described in Clause 3.3.3.3 of AS/NZS 4600. Hence Mb is simply Mc in this case. As specified in Table 1.6 of AS/NZS 4600, the capacity reduction factor (φb) for computing the design member moment capacity is 0.90.

Clause 3.3.3.2 of AS/NZS 4600 gives design rules for laterally unbraced and intermediately braced beams including box, I-beams, T-beams, C- and Z-section beams when cross-sectional distortion does not occur. The basis of the design rules for lateral buckling is described in the following Section 5.2 of this book.

Clause 3.3.3.3 of AS/NZS 4600 gives design rules for beams which undergo distortional buckling, as shown in Fig. 1.18, rather than lateral buckling. This usually occurs when the compression flange of a beam is laterally restrained but the flange and lip are free to rotate about the flange/web junction as shown in Fig. 3.12 and this is specified in Clause 3.3.3.3(a) of

AS/NZS 4600. This mode is sometimes called 'Flange Distortional' and is described in Section 5.3.1 of this book. In some cases, such as for the Hollow Flange Beam and the LiteSteel beam subject to bending, distortional buckling may involve transverse flexure of the web as shown in Fig. 3.15 and 3.16 and this is specified in Clause 3.3.3.3(b) of AS/NZS 4600. This mode is sometimes called 'Lateral Distortional' and is described in Section 5.3.2 of this book.

The basic behaviour of purlins is described in Section 5.4, and design methods for purlins are described in Section 5.5. These include the R-factor design approach in Clause 3.3.3.4 of AS/NZS 4600 which allows for the restraint from sheeting attached by screw-fastening to one flange. Methods for bracing beams against lateral and torsional deformation are described in Clause 4.3 of AS/NZS 4600 and are described in Section 5.6 of this book. Allowance for inelastic reserve capacity of flexural members is included as Clause 3.3.2.3 of AS/NZS 4600 as an alternative to initial yielding described by Clause 3.3.2.2 and specified by Eq 5.1. Inelastic reserve capacity is described in Section 5.7 of this book.

The design for (d) requires computation of the nominal shear capacity (V_V) of the beam and is fully described in Chapter 6 (Webs) of this book. The design for (e) requires computation of the nominal capacity for concentrated load (Rb) (bearing) and is also described in Chapter 6 (Webs) of this book. The interaction of both shear and bearing with section moment is also described in Chapter 6.

5.2 Flexural-Torsional (Lateral) Buckling

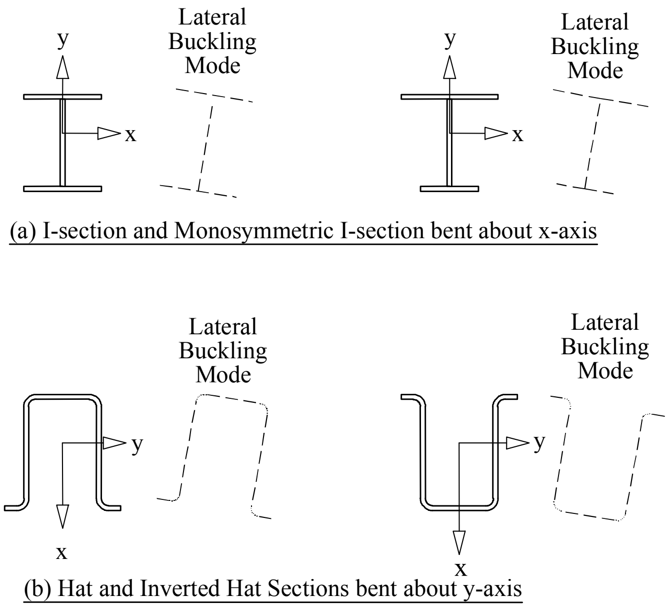
5.2.1 Elastic Buckling of Unbraced Simply Supported Beams

The elastic buckling moment (M_o) of a simply supported and I-beam, monosymmetric I-beam or T-beam bent about the *x*-axis perpendicular to the web as shown in Fig. 5.1(a) with equal and opposite end moments and of unbraced length (l) is given in Refs 5.1 and 5.2 and is equal to:

$$M_o = \frac{\pi\sqrt{EI_y GJ}}{l}\left[\frac{\pi\delta}{2} + \sqrt{\left(\frac{\pi\delta}{2}\right)^2 + \left(1 + \frac{\pi^2 EI_w}{GJl^2}\right)}\right] \qquad (5.4)$$

where

$$\delta = \frac{\pm\beta_x}{l}\sqrt{\frac{EI_y}{GJ}} \qquad (5.5)$$



(a) I-section and Monosymmetric I-section bent about x-axis

(b) Hat and Inverted Hat Sections bent about y-axis

Fig. 5.1 Lateral buckling modes and axes

The value of δ is positive when the larger flange is in compression, is zero for doubly symmetric beams, and is negative when the larger flange is in tension.

Design of Cold-Formed Steel Structures

(To Australian/New Zealand Standard AS/NZS 4600:2005)

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