CHAPTER 8 MEMBERS IN COMBINED AXIAL LOAD AND BENDING

8.1 Combined Axial Compressive Load and Bending - General

Structural members which are subjected to simultaneous bending and compression are commonly called beam-columns. The bending generally results from one of three sources depending upon the application of the beam-column. These sources are shown in Fig. 8.1(a) and are described as follows:

(i) Eccentric axial load of the type usually encountered in columns where the line of action of the axial force is eccentric from the centroid. A typical application is the columns of industrial steel storage racks where the beams apply an eccentric load to the columns as a consequence of the nature of the connections. In the studs in steel framed housing, particular end connections at the top and bottom plates may produce eccentric loading.

(ii) Distributed transverse loading normally resulting from wind forces on sheeting attached to the structural member. A typical application is the purlins in the end spans of industrial buildings where the end wall applies axial load to the purlin and the sheeting applies a distributed load. Another application is the stud walls of steel-framed houses where lateral load from wind, and axial load from upper storeys or the roof can occur simultaneously.

(iii) End moments, shears and axial forces which occur in members of rigid jointed structures such as portal frames, where the members are rigidly connected together using bolted joints.

The combination of concentric axial force and bending moment at a cross-section can be converted to an equivalent eccentric axial force as shown in Fig. 8.1(b). The eccentricity of this axial force defines three different situations. For the monosymmetric section shown in Fig. 8.1(b), these are:

(i) Eccentric compression with bending in the plane of symmetry when $e_x \neq 0$ and $e_y = 0$.

(ii) Eccentric compression with bending about the axis of symmetry when $e_x = 0$ and $e_y \neq 0$.

(iii) Biaxial bending when $e_x \neq 0$ and $e_y \neq 0$.

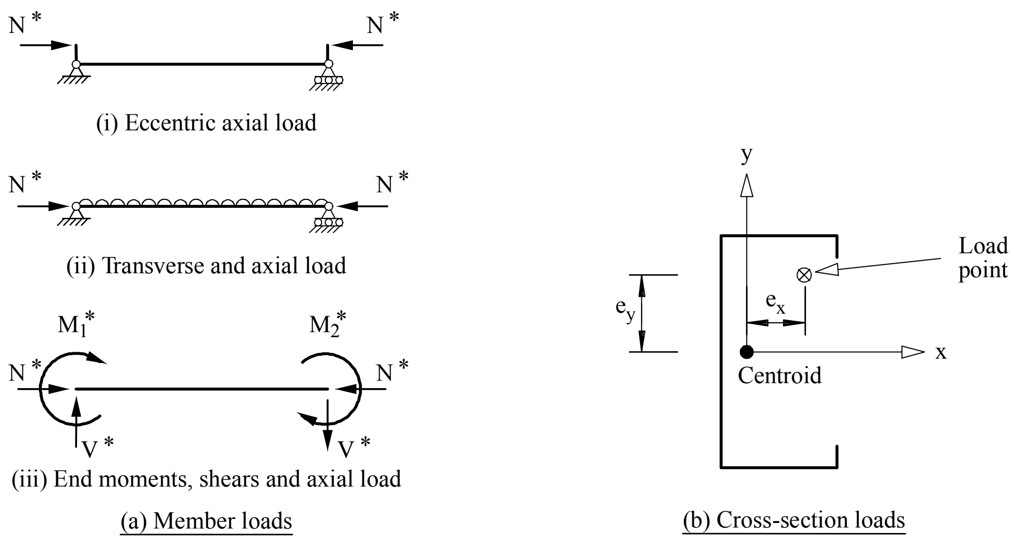

Fig. 8.1 Combined compression and bending

In AS/NZS 4600, Clause 3.5.1 specifies the acceptable combinations of action effects (force, moment) for members subject to combined bending and compression. Clause 3.5.1 uses the design capacity for beams given in Clause 3.3 as well as those for columns given in Clause 3.4. The capacity factors (ϕ_b, ϕ_c) for bending and compression remain the same as when the bending or compression are considered alone.

8.2 Interaction Equations for Combined Axial Compressive Load and Bending

The rules governing combined actions are based on the use of linear interaction equations expressed in terms of axial force and moment as follows.

When $\frac{N^*}{\phi_c N_c} \leq 0.15$

$$\frac{N^*}{\phi_c N_c} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0 \qquad (8.1)$$

When $\frac{N^*}{\phi_c M_c} > 0.15$

(a)
$$\frac{N^*}{\phi_c N_c} + \frac{C_{mx} M_x^*}{\phi_b M_{bx} \alpha_{nx}} + \frac{C_{my} M_y^*}{\phi_b M_{by} \alpha_{ny}} \leq 1.0 \qquad (8.2)$$

(b)
$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0 \qquad (8.3)$$

where

N_c = nominal member capacity of the member in compression determined in accordance with Clause 3.4

M_{bx}, M_{by} = nominal member moment capacity about the *x*- and *y*-axes respectively determined in accordance with Clause 3.3.3

C_{mx}, C_{my} = coefficients for unequal end moments

N_s = nominal section capacity of the member in compression determined in accordance with Clause 3.4, with $f_n = f_y$

α_{nx}, α_{ny} = moment amplification factors

The basis of the linear interaction equations expressed as Eqs (8.1) to (8.3) is given in Ref. 8.1. Eq. (8.2) is a stability check and Eq. (8.3) is a strength check at the supports.

The coefficients (C_{mx}, C_{my}) allow for unequal end moments in beam-columns. They are set out for members free to sway in Fig. 8.2(a) and members braced against sway in Fig. 8.2(b).

The moment amplification factors (α_{nx}, α_{ny}) are defined by Eqs (8.4) and (8.5).

$$\alpha_{nx} = 1 - \frac{N^*}{N_{ex}} \qquad (8.4)$$

$$\alpha_{ny} = 1 - \frac{N^*}{N_{ey}} \qquad (8.5)$$

where
$$N_{ex} = \frac{\pi^2 E I_{bx}}{l_{ebx}^2} \qquad (8.6)$$

and $$N_{ey} = \frac{\pi^2 E I_{by}}{l_{eby}^2} \tag{8.7}$$

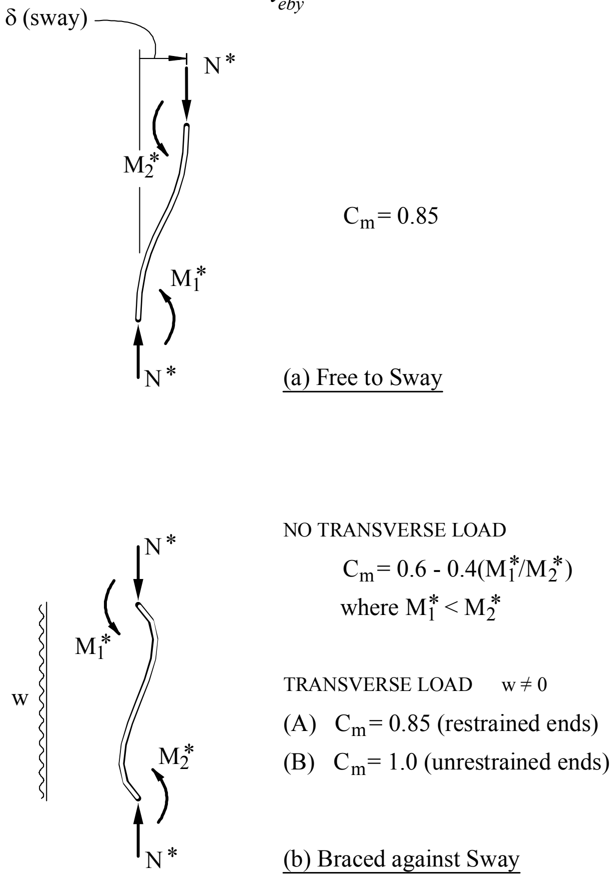

Fig. 8.2 C_m factors

The values of I_{bx}, I_{by} are the second moments of area of the full, unreduced cross-section about the *x*-, *y*-axes respectively. The values of l_{ebx}, l_{eby} are the effective lengths for buckling about the *x*-, *y*-axes respectively. They may be greater than the member length for members in sway frames. The moment amplification factors (α_{nx}, α_{ny}) increase the first order elastic moments (M_x^*, M_y^*) to second order elastic moments ($M_x^* / \alpha_{nx}, M_y^* / \alpha_{ny}$).

AS/NZS 4600 does not mention second order elastic analyses in Clause 1.6.2 Structural Analysis and Design. It is presumed that all analyses are first order elastic since the second order effects are included by way of the amplification factors. However, it seems reasonable for M_x^*, M_y^* to be based on second order elastic analyses if $C_{mx} / \alpha_{nx} = 1.0$ and $C_{my} / \alpha_{ny} = 1.0$. The resulting equations are similar to Clause 8.4.4 of AS 4100-1998 (Ref. 1.10) except that N_c in Eqs (8.1) and (8.2) should still be based on the effective length (l_e) and not the actual length as for Clause 8.4.4 of AS 4100-1990. Further research is required in this area for cold-formed members.

8.3 Monosymmetric Sections under Combined Axial Compressive Load and Bending

The behaviour of monosymmetric sections depends upon whether the sections are bent in the plane of symmetry, about the axis of symmetry or both.

8.3.1 Sections Bent in a Plane of Symmetry

Monosymmetric sections bent in the plane of symmetry may fail by either:

(a) deflecting gradually in the plane of symmetry without twisting, followed by yielding or local buckling at the location of maximum moment. This mode is denoted by the curves labelled "Flexural Yielding" in Fig. 8.3, which has been developed from the study

Design of Cold-Formed Steel Structures

(To Australian/New Zealand Standard

AS/NZS 4600:2005)

by

Gregory J. Hancock BSc BE PhD DEng

Bluescope Steel Professor of Steel Structures
Dean
Faculty of Engineering & Information Technologies
University of Sydney

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