8.3 Combined Bending and Axial Compression

In this section:

ϕ = 0.9 (Table 3.4 of AS 4100)

ϕM_{sx} = design section moment capacity for bending about the major principal x-axis

ϕM_{sy} = design section moment capacity for bending about the minor principal y-axis

N_c^* = design axial compressive force

ϕN_s = design section capacity in compression

ϕN_{cx} = design member capacity in compression, buckling about the x-axis

ϕN_{cy} = design member capacity in compression, buckling about the y-axis

8.3.1 Compression and Uniaxial Bending – about the major principal x-axis

For a member subject to both uniaxial bending about the major principal x-axis and axial compression, the following condition must be satisfied:

$$M_x^* \le \min.[\phi M_{rx}; \phi M_{ix}; \phi M_{ox}] \qquad \text{EQN 8.3.1}$$

where ϕ = 0.9 (Table 3.4 of AS 4100)

M_x^* = design bending moment about the major principal x-axis

ϕM_{rx} = design section moment capacity (ϕM_{sx}) for bending about the major principal x-axis reduced by axial force (see Section 8.3.1.1 following)

ϕM_{ix} = design in-plane member moment capacity for bending about the major principal x-axis (see Section 8.3.1.2(a) following)

ϕM_{ox} = design out-of-plane member moment capacity for bending about the major principal x-axis (see Section 8.3.1.2(b) following)

8.3.1.1 Section Capacity

The value of ϕM_{rx} must be determined at all points along the member and the minimum value used to satisfy EQN 8.3.1.

$$\phi M_{rx} = \phi M_{sx}\left(1-\frac{N_c^*}{\phi N_s}\right) \qquad \text{(Clause 8.3.2 of AS 4100)}$$

Alternatively, for doubly symmetric I-sections, which are compact about the x-axis with k_f = 1.0 and are subject to bending and axial compression

$$\phi M_{rx} = 1.18\phi M_{sx}\left(1-\frac{N_c^*}{\phi N_s}\right) \le \phi M_{sx} \qquad \text{(Clause 8.3.2 of AS 4100)}$$

For doubly symmetric I-sections, which are not compact about the x-axis with k_f < 1.0 and are subject to bending and axial compression

$$\phi M_{rx} = \phi M_{sx}\left(1-\frac{N_c^*}{\phi N_s}\right)\left[1+0.18\left(\frac{82-\lambda_w}{82-\lambda_{wy}}\right)\right] \le \phi M_{sx} \qquad \text{(Clause 8.3.2 of AS 4100)}$$

where λ_w = the element slenderness of the web (Clause 6.2.3 of AS 4100)

$$= \frac{d_1}{t_w}\sqrt{\frac{f_y}{250}} \qquad \text{(where } f_y = \min.\ [f_{yf}; f_{yw}]\text{)}$$

λ_{wy} = the web yield slenderness limit (Table 6.2.4 of AS 4100)

= 45 for hot-rolled I-sections considered in this publication.

= 35 for welded I-sections considered in this publication.

8.3.1.2 Member Capacity

This section only applies to members analysed using an elastic method of analysis. Where there is sufficient restraint to prevent lateral buckling, only the in-plane requirements of this Section need to be satisfied. If there is insufficient restraint to prevent lateral buckling, then both the in-plane and out-of-plane requirements of this Section need to be satisfied.

(a) In-plane capacity

$$\phi M_{ix} = \phi M_{sx}\left(1-\frac{N_c^*}{\phi N_{cx}}\right) \qquad \text{(Clause 8.4.2.2 of AS 4100)}$$

For braced and sway members, the above value of ϕN_{cx} is calculated using an effective length factor (k_{ex}) equal to 1.0 (i.e. $l_{ex} = l$), unless a lower value of k_{ex} has been calculated for a braced member, provided that $N^* \leq \phi N_{cx}$ where the value of ϕN_{cx} in this inequality is calculated using the value of k_{ex}, calculated from Clauses 4.6.3.2, 4.6.3.3 or 4.6.3.5 of AS 4100.

(b) Out-of-plane capacity

$$\phi M_{ox} = \phi M_{bx}\left(1-\frac{N_c^*}{\phi N_{cy}}\right) \qquad \text{(Clause 8.4.4.1 of AS 4100)}$$

where ϕM_{bx} = design member moment capacity for bending about the major principal x-axis, for a member without full lateral restraint.

Clauses 8.4.2.2 and 8.4.4.1 of AS 4100 also provide a higher tier method for evaluating M_{ix} and M_{ox} respectively for doubly symmetric I-sections, these methods being dependent on the ratio of the member's end bending moments. Due to the variable nature of these end bending moments, the further consideration of this higher tier method is beyond the scope of this publication.

8.3.1.3 Tables

Tables 8.1-1 to 8.1-12 list ϕM_{sx}, ϕN_s and expressions for ϕM_{rx} (comp) as a function of 'n' (ϕM_{rx} as defined in Section 8.3.1.1). Designers should evaluate $n = N_C^*/\phi N_s$, then use it to calculate the value of ϕM_{rx} using the equation in the table and ensure that it is **less than or equal to** the design section capacity ϕM_{sx}. The 8.1 series tables also provide references to other tables (for ϕM_b, ϕN_{cx} and ϕN_{cy} in Parts 5 and 6 of this publication) in order to be able to evaluate ϕM_{ix} and ϕM_{ox}.

8.3.2 Compression and Uniaxial Bending – about the minor principal y-axis

For a member subject to uniaxial bending about the minor principal y-axis and axial compression, the following condition must be satisfied:

$$M_y^* \leq \text{min. } [\phi M_{ry}; \phi M_{iy}] \qquad \text{EQN 8.3.2}$$

where ϕ = 0.9 (Table 3.4 of AS 4100)

M_y^* = design bending moment about the minor principal y-axis

ϕM_{ry} = design section moment capacity (ϕM_{sy}) for bending about the minor principal y-axis reduced by axial force (see Section 8.3.2.1)

ϕM_{iy} = design in-plane member moment capacity for bending about the minor principal y-axis (see Section 8.3.2.2)

8.3.2.1 Section Capacity

The value of ϕM_{ry} must be determined at all points along the member and the minimum value is used to satisfy EQN 8.3.2:

$$\phi M_{ry} = \phi M_{sy}\left(1 - \frac{N_c^*}{\phi N_s}\right) \qquad \text{(Clause 8.3.3 of AS 4100)}$$

Alternatively, for doubly symmetric I-sections, which are compact about the y-axis and are subject to bending and compression:

$$\phi M_{ry} = 1.19\phi M_{sy}\left[1 - \left(\frac{N_c^*}{\phi N_s}\right)^2\right] \leq \phi M_{sy} \qquad \text{(Clause 8.3.3 of AS 4100)}$$

8.3.2.2 Member Capacity

This section only applies to members analysed using an elastic method of analysis. For bending about the minor principal y-axis only the in-plane requirements need to be satisfied.

In-plane capacity

$$\phi M_{iy} = \phi M_{sy}\left(1 - \frac{N_c^*}{\phi N_{cy}}\right) \qquad \text{(Clause 8.4.2.2 of AS 4100)}$$

For braced and sway members, the above value of ϕN_{cy} is calculated using an effective length factor (k_{ey}) equal to 1.0 (i.e. l_{ey} = l), unless a lower value of k_{ey} has been calculated for a braced member, provided that $N^* \leq \phi N_{cy}$ where the value of ϕN_{cy} in this inequality is calculated using the value of k_{ey}, calculated from Clauses 4.6.3.2, 4.6.3.3 or 4.6.3.5 of AS 4100.

Clause 8.4.2.2 of AS 4100 also provides a higher tier method for evaluating M_{iy} for doubly symmetric I-sections these methods being dependent on the ratio of the member's end bending moments. Due to the variable nature of these end bending moments, the further consideration of this higher tier method is beyond the scope of this publication.

8.3.2.3 Tables

Tables 8.1-1 to 8.1-12 list ϕM_{sy}, ϕN_s and expressions for ϕM_{ry}. Designers should evaluate n = $N_C^*/\phi N_s$, then calculate the value of ϕM_{ry} using the equation in the table and ensure that it is **less than or equal to** the design section capacity ϕM_{sy}. The 8.1 series tables also provide references to other tables (for ϕN_{cy}) in Part 6 of this publication to evaluate ϕM_{iy}.

8.3.3 Compression and Biaxial Bending

For a member subject to biaxial bending and axial compression, both the inequalities specified in Sections 8.3.3.1 and 8.3.3.2 must be satisfied.

8.3.3.1 Section Capacity

$$\frac{N_c^*}{\phi N_s} + \frac{M_x^*}{\phi M_{sx}} + \frac{M_y^*}{\phi M_{sy}} \leq 1 \qquad \text{(Clause 8.3.4 of AS 4100)}$$

Alternatively, for doubly symmetric I-sections which are compact about both the x- and y-axes, sections at all points along the member shall satisfy:

$$\left(\frac{M_x^*}{\phi M_{rx}}\right)^{\gamma} + \left(\frac{M_y^*}{\phi M_{ry}}\right)^{\gamma} \leq 1 \qquad \text{(Clause 8.3.4 of AS 4100)}$$

where $\gamma = 1.4 + \left(\frac{N_c^*}{\phi N_s}\right) \leq 2.0$

ϕM_{rx} and ϕM_{ry} are calculated using the alternative methods presented in Sections 8.3.1.1 and 8.3.2.1.

8.3.3.2 Member Capacity

$$\left(\frac{M_x^*}{\phi M_{cx}}\right)^{1.4} + \left(\frac{M_y^*}{\phi M_{iy}}\right)^{1.4} \leq 1 \qquad \text{(Clause 8.4.5.1 of AS 4100)}$$

where ϕM_{cx} = lesser of ϕM_{ix} and ϕM_{ox} (see Section 8.3.1.2)

and ϕM_{iy} is calculated using the method presented in Section 8.3.2.2.

8.3.3.3 Tables

Tables 8.1-1 to 8.1-12 list ϕN_s, ϕM_{sx} and ϕM_{sy}. As noted in Sections 8.3.1.3 and 8.3.2.3, the design capacities ϕM_{rx}, ϕM_{ry}, ϕM_{ix}, ϕM_{iy} and ϕM_{ox} can also be calculated from these tables.

8.4 Combined Bending and Axial Tension

In this section:

ϕ = 0.9 (Table 3.4 of AS 4100)

ϕM_{sx} = design section moment capacity for bending about the major principal x-axis

ϕM_{sy} = design section moment capacity for bending about the minor principal y-axis

N_t^* = design axial tension force

ϕN_t = design section capacity in axial tension

8.4.1 Tension and Uniaxial Bending – about the major principal x-axis

For a member subject to uniaxial bending about the major principal x-axis and axial tension, the following condition must be satisfied:

$$M_x^* \leq \min.\ [\phi M_{rx};\ \phi M_{ox}] \qquad \text{EQN 8.4.1}$$

where ϕ = 0.9 (Table 3.4 of AS 4100)

M_x^* = design bending moment about the major principal x-axis

ϕM_{rx} = design section moment capacity (ϕM_{sx}) for bending about the major principal x-axis reduced by axial force (see Section 8.4.1.1)

ϕM_{ox} = design out-of-plane member moment capacity for bending about the major principal x-axis (see Section 8.4.1.2 (a))