PART 4 METHODS OF STRUCTURAL ANALYSIS

4.1 Methods of Determining Design Action Effects

This section provides guidance on calculating design action effects as required by AS 4100. The methods of analysis recognised by AS 4100 are:

(a) first-order elastic analysis with moment amplification (Clause 4.4.2 of AS 4100)
(b) second-order elastic analysis (Appendix E of AS 4100)
(c) plastic analysis with moment amplification (Clause 4.5 of AS 4100), and
(d) advanced analysis (Appendix D of AS 4100).

These four methods consider the interaction of load and deformation that produce second-order effects. For members subject to bending and axial force, second-order effects (known as $P - \Delta$ and $P - \delta$ effects) can increase the design bending moment. Method (a) without moment amplification – i.e. first-order elastic analysis – does not consider these second-order effects and may be used for members with bending moments only, axial tension or compression force only and, for braced members, combined bending moments and tension forces.

In general, structural analysis methods (a) – with and without moment amplification – and (b) are most commonly used. However, (b) can only be effectively used via computer methods. Method (c) is currently not permitted by AS 4100 for structural hollow sections though research work is ongoing in this area and method (d) is not commonly used. Consequently, method (a) will be considered further as methods (b), (c) and (d) are beyond the scope of this publication. The following Sections are presented as a guide for the designer when using method (a).

The tabulated values in Parts 5, 6, 7, 8 and 9 may be used for design in those cases where second-order effects:

- can be neglected (members with only: tension force; compression force; bending moments, or; for braced members, combined bending moments and tension force)
- are accounted for by using moment amplification factors in conjunction with a first-order elastic analysis
- are accounted for in a second-order elastic analysis.

4.2 Moment Amplification for First-Order Elastic Analysis

For a member subjected to combined bending moment and axial force, the bending moments are amplified by the presence of axial force. This occurs to both isolated, statically determinate members and members in a statically indeterminant frame. A first-order elastic analysis alone does not consider second-order effects, however, *moment amplification* accounts for the second-order effects. The moment amplification factor is calculated differently for braced and sway members as shown below.

4.2.1 Braced Members

In a braced member the transverse displacement of one end of the member relative to the other is effectively prevented. The moment amplification factor for a braced member is δ_b.

If a first-order elastic analysis is carried out then δ_b is used to amplify the bending moments between the ends of the member (Clause 4.4.2.2 of AS 4100). If δ_b is greater than 1.4, a second-order elastic analysis must be carried out in accordance with Appendix E of AS 4100.

δ_b can be calculated from the flow chart in Figure 4.1. The design bending moment is given by:

$M^* = M_m^*$ (for braced members subject to axial tension or with zero axial force)

$M_m^* = \delta_b M_m^*$ (for braced members subject to compression)

where M_m^* is the maximum design bending moment calculated from a first-order analysis.

4.2.1.1 Calculation of c_m

The factor for unequal moments (c_m) is used in the calculation of δ_b. If a braced member is subject *only to end moments* then:

$c_m = 0.6 - 0.4\beta_m$ (Clause 4.4.2.2 of AS 4100)

where β_m is the ratio of the smaller to the larger bending moment at the ends of the member, taken as positive when the member is bent in reverse curvature.

If the member is subjected to transverse loading, β_m is calculated as follows:

(a) $\beta_m = -1.0$ (conservative) (Clause 4.4.2.2(a) of AS 4100)

(b) β_m is obtained by matching the moment distribution options shown in Figure 4.4.2.2 of AS 4100

(c) β_m is based on the midspan deflection. (Clause 4.4.2.2(c) of AS 4100)

4.2.2 Sway Members

In a sway member the transverse displacement of one end of the member relative to the other is not effectively prevented. The moment amplification factor for a sway member is δ_s.

The bending moments calculated from a first-order elastic analysis are modified by the moment amplification factor (δ_m) which is the greater of δ_b (see Section 4.2.1) and δ_s (Clause 4.4.2.3 of AS 4100). If δ_m is greater than 1.4 a second-order elastic analysis must be used in accordance with Appendix E of AS 4100.

δ_b and δ_s are calculated from the flow charts shown in Figures 4.1 and 4.2 and the design bending moment is given by:

$M^* = \delta_m M_m^*$

4.2.3 Elastic Flexural Buckling Loads

Elastic flexural buckling loads (N_{om}) are required for the calculation of δ_b and δ_m. Values of N_{om} for various effective lengths (L_e) are determined from Clause 4.6.2 of AS 4100 by:

$$N_{om} = \frac{\pi^2 EI}{(k_e L)^2}$$

where $k_e L = L_e$ = effective length. k_e is given in Figure 6.1 for members with idealised end restraints. For braced or sway members in frames, k_e depends on the ratio (γ) of the compression member stiffness to the end restraint stiffness, calculated at each end of the member. Refs. [4.1,4.2] provide worked examples for the calculation of effective lengths and moment amplification factors for members in those instances.

For a specific effective length, reference can be made to the Dimensions and Properties Tables in Part 3 (i.e. Tables 3.1-1 to 3.1-6 as appropriate) to determine I (i.e. I_x or I_y) and then simply evaluate the above equation for N_{om}.

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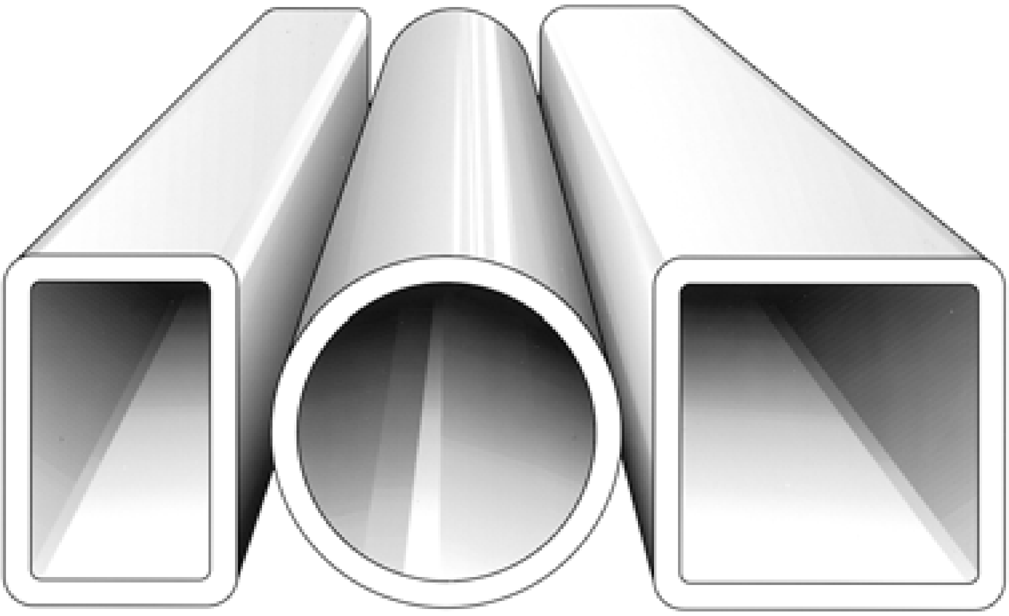

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LIMIT STATES EDITION TO AS 4100-1998 $S^* \leq \phi R_u$

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NOTE: SEE SECTION 2.1 FOR THE SPECIFIC MATERAL STANDARD (AS 1163) REFERRED TO BY THE SECTION TYPE AND STEEL GRADE IN THIS PUBLICATION