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)

All methods of analysis are discussed in detail in the commentary to AS 4100 [Ref 4.2].

These Design Capacity Tables are intended to be used with first-order and second-order elastic analysis, which are the most common methods of analysis in use currently. For simple structural members, hand methods of analysis are most common, while for frames involving a number of members, analysis is usually by means of a computer program.

In first-order elastic analysis, it is assumed that the member remains elastic under the action of the design loads for all strength limit states. Second order effects which are caused by changes in the geometry of the member are not accounted for in this type of analysis. Consequently, some adjustment must be made for second-order effects and AS 4100 includes methods of making a suitable adjustment to the calculated design actions.

Second order elastic analysis does account for the effects of the design loads acting on the structure and its members in their displaced and deformed configuration. No adjustment is required to the calculated design actions with a second-order analysis. Second-order effects can be substantial in some frames.

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 for both isolated, statically determinate members and members in a statically indeterminate frame. A first-order elastic analysis alone does not consider second-order effects, however, moment amplification can be used to account for the second-order effects. The moment amplification factor is calculated differently for braced and sway members as explained in the following sub-sections.

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 denoted by 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 calculated to be 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 by following the sequence shown in the flow chart in Figure 4.1, and is given by:

$$\delta_b = \frac{c_m}{1-\left(\dfrac{N^*}{N_{omb}}\right)} \geq 1$$

The design bending moment (M^*) is then given by:

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

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

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

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 the factor c_m is calculated as follows:

$c_m = 0.6 - 0.4\beta_m \leq 1.0$ (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, the same expression for c_m shall be used provided β_m is calculated using one of the following methods:

(a) β_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 and selecting the nominated value in the table (Clause 4.4.2.2(b) of AS 4100)

(c) β_m is based on the midspan deflection for two cases. (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 denoted by 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. A detailed explanation of the procedure for calculating δ_s may be found in Ref [4.2].

δ_b and δ_s are calculated by following the sequence given in the flow charts shown in Figure 4.1 and 4.2. The design bending moment is given by:

$$M^* = \delta_m M^*_m$$

4.2.3 Elastic Flexural Buckling Loads

Elastic flexural buckling loads (N_{omx}, N_{omy}) are required for the calculation of δ_b and δ_m. Values of N_{om} are determined from Clause 4.6.2 of AS 4100 using the expression:

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

where $k_e l = l_e$ = effective length. k_e is determined in accordance with Clause 4.6.3 of AS 4100. l is the member length from centre-to-centre of its intersection with supporting members and I is the second moment of area about the axis of interest (I_x or I_y). 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. Section 4.3 provides worked examples for the calculation of elastic flexural buckling loads and moment amplification factors for members.

Reference can be made to the Dimensions and Properties Tables in Part 3 (i.e. Tables 3.1-1 to 3.1-13 as appropriate) to determine I (i.e. I_x or I_y) for use in the above equation for N_{om}. No tables relating N_{om} to effective length are provided in this Publication.