CHAPTER 3 BUCKLING MODES OF THIN-WALLED MEMBERS IN COMPRESSION AND BENDING

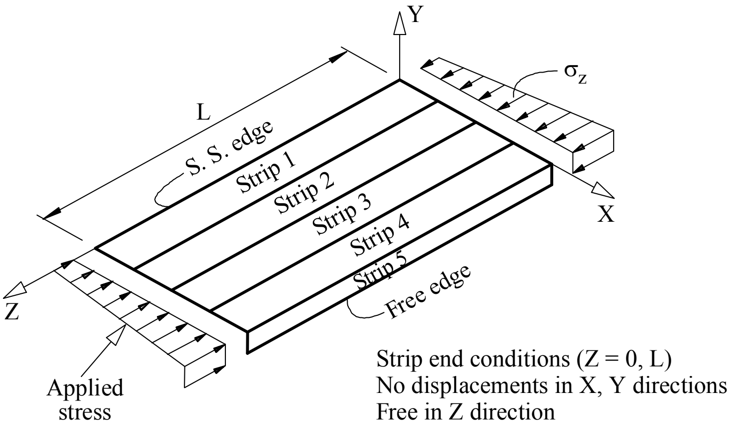
3.1 Introduction to the Finite Strip Method

The finite strip method of buckling analysis of thin-walled sections is a very efficient tool for investigating the buckling behaviour of cold-formed members in compression and bending. The buckling modes which are calculated by the analysis can be drawn using computer graphics and consequently it is a useful method for demonstrating the different modes of buckling of thin-walled members. It is the purpose of this chapter to use the finite strip buckling analysis to describe generally the different modes of buckling of cold-formed members in compression and bending. Although this description is not central to the application of the design methods described in later chapters, it facilitates an understanding of these methods. In addition, the finite strip method of analysis can be used to give more accurate values of the local buckling and distortional buckling stresses than is available by simple hand methods. It is permissible to use these more accurate values of local buckling stress in design as specified in Clause 2.2.1.2 of AS/NZS 4600, and in some cases considerable economies can be achieved, particularly for sections in combined compression and bending. It is also possible to use the distortional buckling values in design as specified in Clauses 3.3.3.3 and 3.4.6 of AS/NZS 4600.

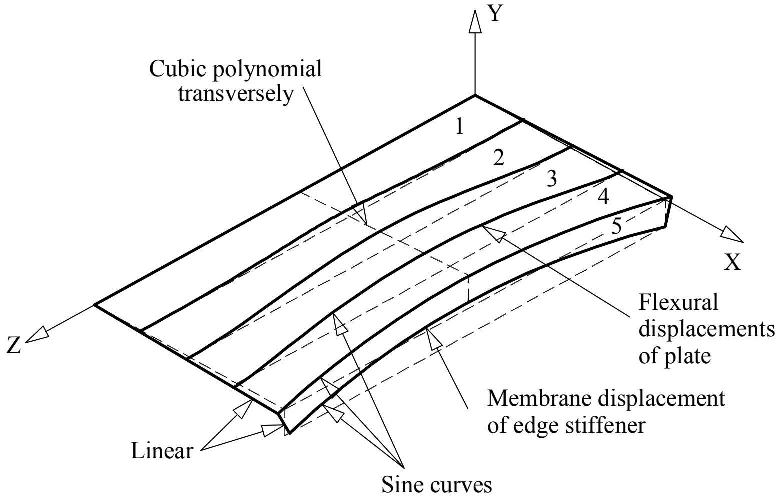
The semi-analytical finite strip method used in this book is the same as that described by Cheung (Ref. 3.1) for the stress analysis of folded plate systems and subsequently developed by Przmieniecki (Ref. 3.2) for the local buckling analysis of thin-walled cross-sections. Plank and Wittrick (Ref. 3.3) incorporated membrane buckling displacements in addition to plate flexural displacements to permit the study of a wide range of buckling modes ranging from local through distortional to flexural and flexural-torsional. An alternative method called the spline finite strip method is a development of the semi-analytical finite strip method. It can be used to account for non-simple end boundary conditions and was developed for buckling analyses of thin flat-walled structures by Lau and Hancock (Ref. 3.4). A brief comparison of the two methods when applied to a channel section of fixed length is given in Section 3.2.3.

A computer program THIN-WALL has been developed at the University of Sydney to perform a finite strip buckling analysis of thin-walled sections under compression and bending. The detailed method of operation of the program on a microcomputer is described in Ref. 1.33.

The semi-analytical finite strip method involves subdividing a thin-walled member, such as the edge stiffened plate in Fig. 3.1(a), into longitudinal strips. Each strip is assumed to be free to deform both in its plane (membrane displacements) and out of its plane (flexural displacements) in a single half sine wave over the length of the section being analysed as shown in Fig. 3.1(b). The ends of the section under study are free to deform longitudinally but are prevented from deforming in a cross-sectional plane. The buckling modes computed are for a single buckle half-wavelength. Details of the analytical method and its application to cases where multiple half-wavelengths occur within the length of a section under study are given in Ref. 3.5. Each strip in the cross-section is assumed to be subjected to a longitudinal compressive stress (σ_z) which is uniform along the length of the strip and varies linearly from one nodal line to the other nodal line as shown in Fig. 3.1(a).



(a) Strip subdivision



(b) Membrane and flexural buckling displacements

Fig. 3.1 Finite strip analysis of edge stiffened plate

This allows the section under study to be subjected to a range of longitudinal stress distributions varying from pure compression to pure bending. Program THIN-WALL initially performs a stress analysis for a section subject to compression, bending and torsion to compute the longitudinal stresses for input to the semi-analytical finite strip buckling analysis.

3.2 Monosymmetric Column Study

3.2.1 Unlipped Channel

To demonstrate the different ways in which a monosymmetric channel column may buckle under both concentric and eccentric load, the results of a semi-analytical finite strip buckling analysis of an unlipped channel of depth 152 mm, flange width 50 mm, and thickness 3.2 mm are described and discussed. A stability analysis of the channel shown in Fig. 3.2 subjected to a uniform compressive stress produces the two graphs shown in Fig. 3.3. These graphs represent the buckling load (uniform compressive stress multiplied by the gross area) versus the half-wavelength of the buckle for the first two modes of buckling. A minimum (Point A) occurs in the lower curve at a half-wavelength equal to approximately 160 mm and corresponds to local buckling in the symmetrical mode shown. Similarly at Point B in the upper curve, a minimum occurs at a half-wavelength equal to approximately 100 mm which corresponds to the second mode of local buckling with the anti-symmetrical mode shape shown.

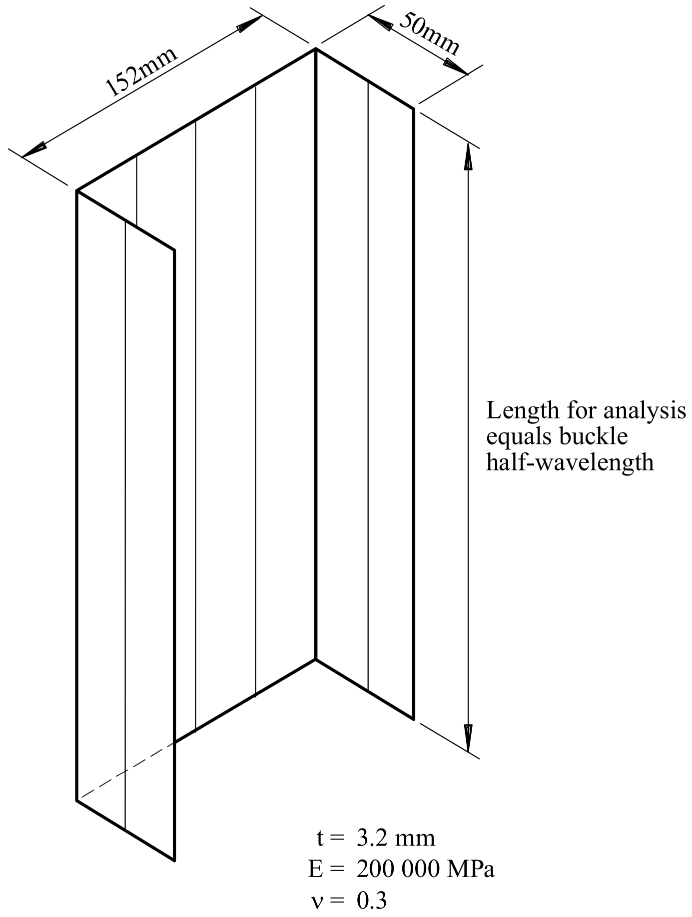


Fig. 3.2 Finite strip subdivision of unlipped channel

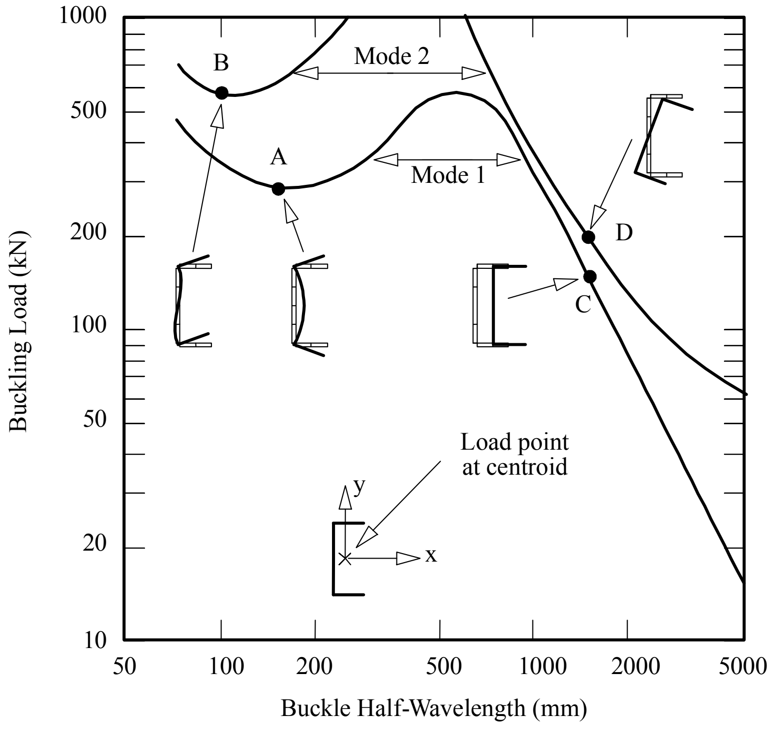


Fig. 3.3 Unlipped channel section buckling load versus half-length for concentric compression

Design of Cold-Formed Steel Structures

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

by

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