CHAPTER 4 STIFFENED AND UNSTIFFENED COMPRESSION ELEMENTS

4.1 Local Buckling

Local buckling involves flexural displacements of the plate elements, with the line junctions between plate elements remaining straight as shown in Figs 3.6, 3.7, 3.9 and 3.12. The elastic critical stress for local buckling has been extensively investigated and summarised by Timoshenko and Gere (Ref. 3.6), Bleich (Ref. 4.1), Bulson (Ref. 4.2) and Allen and Bulson (Ref. 4.3). The elastic critical stress for local buckling of a plate element in compression, bending or shear is given by

$$f_{cr} = \frac{k\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 \tag{4.1}$$

where *k* is called the plate local buckling coefficient and depends upon the support conditions, and where (*b*/*t*) is the plate slenderness which is the plate width (*b*) divided by the plate thickness (*t*).

A summary of plate local buckling coefficients (*k*) with the corresponding half-wavelengths of the local buckles is shown in Fig. 4.1. For example, a plate with simply supported edges on all four sides and subjected to uniform compression will buckle at a half-wavelength equal to the plate width (*b*) with a plate buckling coefficient (*k*) of 4.0. A plate with one longitudinal edge free and the other simply supported will buckle at a half wavelength equal to the plate length (*L*) and if this is sufficiently long, the plate buckling coefficient will be 0.425. However, if the half-wavelength of the buckle is restricted to a length equal to twice its width (L = 2b) then the buckling coefficient will be approximately 0.675 as set out in Fig. 4.1.

For the unlipped channel shown in Fig. 3.2 and subjected to uniform compression, if each flange and the web are analysed in isolation by ignoring the rotational restraints provided by the adjacent elements, then the buckling coefficients are k = 0.425 for the flanges and k = 4.0 for the web. These produce buckling stresses of 336 MPa for the flanges at an infinite half-wavelength and 334 MPa for the web at a half-wavelength of 149 mm. A finite strip buckling analysis shows that the three elements buckle simultaneously at the same half-wavelength of approximately 160 mm at a compressive stress of 350 MPa. This stress is higher than either of the stresses for the isolated elements because of the changes required to make the half-wavelengths compatible.

For the lipped channel purlin shown in Fig. 3.11, the buckling coefficients for the web in bending, the flange in uniform compression, and the lip in near uniform compression are *23.9*, *4.0* and *0.425* respectively. The corresponding buckling stresses are *440* MPa, *404* MPa and *985* MPa respectively. In this case, a finite strip buckling analysis shows that the three elements buckle at a stress and half-wavelength of *450* MPa and *90* mm respectively.

For both of the cases described above, a designer would not normally have access to an interaction buckling analysis and would use the lowest value of buckling stress in the cross-section considering the individual elements in isolation. Clause 2.2.1.2 of AS/NZS 4600 allows values of the local buckling coefficient (*k*) based on a rational elastic buckling analysis to be used in design.

Case	Boundary Conditions	Loading	Buckling Coefficient (k)	Half - Wavelength
1	S.S / S.S S.S / S.S	Uniform Compression	4.0	b
2	Built-in / S.S S.S / Built-in	Uniform Compression	6.97	0.66b
3	S.S / S.S S.S / Free	Uniform Compression	0.425 0.675	L = ∞ L = 2b
4	Built-in / S.S S.S / Free	Uniform Compression	1.247	1.636b
5	S.S / S.S S.S / S.S	Pure Bending	23.9	0.7b
6	S.S / S.S S.S / S.S	Bending + Compression	7.81	b
7	Free / S.S S.S / S.S	Bending + Compression	0.57	L = ∞
8	S.S / S.S S.S / S.S	Pure Shear	5.35 9.35	L =∞ L = b

L = Plate length, b = Plate width

Fig. 4.1 Plate buckling coefficients

4.2 Postbuckling of Plate Elements in Compression

Local buckling does not normally result in failure of the section as does flexural (Euler) buckling in a column. A plate subjected to uniform compressive strain between rigid frictionless platens will deform after buckling as shown in Fig 4.2(a), and will redistribute the longitudinal membrane stresses from uniform compression to those shown in Fig. 4.2(b). This will occur irrespective of whether the plate is a stiffened or an unstiffened element. The plate element will continue to carry load although with a stiffness reduced to 40.8% of the initial linear elastic value for a square stiffened element and to 44.4% for a square unstiffened element (Ref. 4.2). However, the line of action of the compressive force in an unstiffened element will move towards the stiffened edge in the postbuckling range.

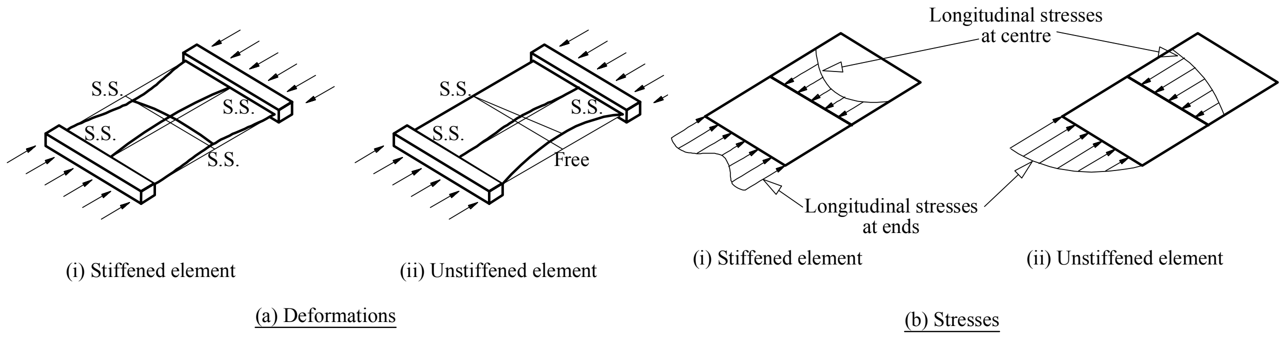

Fig. 4.2 Postbuckled plates

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

fourth edition - 2007

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