Available online at www.sciencedirect.com
ScienceDirect
Thin-Walled Structures 44 (2006) 1118–1128
THIN-WALLED STRUCTURES
www.elsevier.com/locate/tws

Local buckling and post-local buckling redistribution of stress in slender plates and sections

M.R. Bambach

Monash University, Melbourne, Australia

Received 18 April 2006; received in revised form 1 September 2006; accepted 12 October 2006
Available online 28 November 2006

Abstract

Cold-formed open steel sections are comprised of component plates termed stiffened elements (webs) and unstiffened elements (flanges). The local buckling and post-local buckling behaviour of sections may be determined from the behaviour of the component plates. Much research effort has documented the theoretical elastic local buckling of plates and sections, however until recently few experimental studies have been reported on the local buckling and post-local buckling behaviour of unstiffened plates. This paper presents experimental and numerical studies of unstiffened plates and sections that contain them in both compression and bending, and in particular analyses the mechanism that provides post-buckling strength. It is shown that, as with stiffened elements, the mechanism is the post-local buckling redistribution of stress, however unlike stiffened elements this redistribution can occur to such an extent that tensile stresses commonly form in axially compressed slender elements. The stress distributions at ultimate are compared with current international cold-formed steel specifications.

Keywords: Unstiffened plates; Elastic local buckling; Post-local buckling; Slender sections; Stress redistribution

1. Introduction

Compression members such as the unlipped channel shown in Fig. 1 will locally buckle in a number of half-wavelengths and will retain this mode shape into the post-local buckling range, until localisation occurs in one of the half-waves propagating failure. It is well-known that loads at failure may be considerably higher than those at which local buckling occurs, due to the redistribution of longitudinal stresses from the flexible to the stiff parts of the component plates. The nodal lines between locally buckled cells remain straight in this condition. It is commonly understood that in the stiffened element, supported along both longitudinal edges, the longitudinal stress pattern across the width of the loaded edges changes from a condition of uniform stress prior to local buckling, to that shown in Fig. 2(i) in the post-buckled range. The stresses redistribute away from the deformed centre of the plate to the supported edges. For very slender stiffened elements, such as the one shown in Fig. 3 [1] with a slenderness ratio of 5 (Eqs. (1) and (2)), the redistribution can occur to such an extent that the stress in the centre of the plate in the buckled region can become zero. For stiffened elements with even greater slenderness ratios the stresses in the centre can become tensile, however for sections with practical b/t ratios this will not be the case. Stress redistribution in stiffened elements was first noted by von Karmen et al. [2], who termed the stiffer regions the "effective widths" of the plate. The concept was later further developed by Winter [3], who produced the well known effective width Eq. (3) for stiffened elements in compression. The application of the effective width principle is shown in Fig. 3 for the slender stiffened element, where the effective widths are assumed to carry load to the yield point of the material

$$\lambda = \sqrt{\frac{f_y}{f_{cr}}}, \tag{1}$$

$$fcr = \frac{k\pi^2 E}{12(1-\upsilon^2)(b/t)^2}, \tag{2}$$

E-mail address: mike.bambach@eng.monash.edu.au.

0263-8231/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tws.2006.10.005

$$\frac{be}{b} = \sqrt{\frac{f_{cr}}{f_y}}\left(1 - 0.22\sqrt{\frac{f_{cr}}{f_y}}\right). \tag{3}$$

In Eq. (1) f_y is the yield stress of the material and f_{cr} is the elastic buckling stress. In Eq. (2) E is the Young's elastic modulus of the material, v is Poisson's ratio, b is the plate width, t is the plate thickness and k is the elastic buckling coefficient.

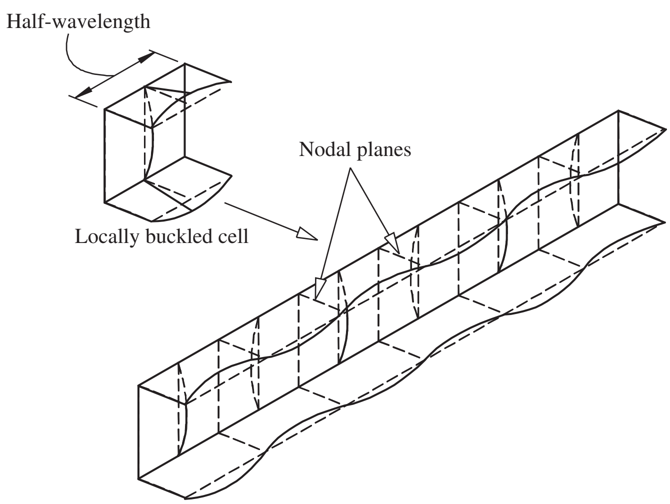

Fig. 1. Locally buckled slender column.

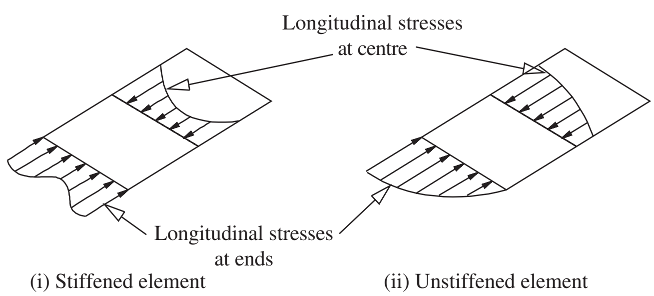

Fig. 2. Post-buckled plates.

In the 1970s the effective width method was extended to unstiffened elements, supported along one longitudinal edge only. Winter [4] and Kalyanaraman et al. [5] performed tests on sections that contained unstiffened elements in pure compression, and the effective width Eq. (3) was modified to Eq. (4) for unstiffened elements in compression. It was understood that again, the post-buckling strength was a result of the redistribution of stress away from the buckled regions to the unbuckled regions, i.e. away from the unsupported edge towards the supported edge as shown in Fig. 2(ii). It was recognised as possible that in slender unstiffened elements the stresses may redistribute to such an extent that tensile stresses may develop at the unsupported edge. Since these and future tests were performed on sections not plates, this phenomenon has not been adequately documented and described for unstiffened elements

$$\frac{be}{b} = 1.19\sqrt{\frac{f_{cr}}{f_y}}\left(1 - 0.298\sqrt{\frac{f_{cr}}{f_y}}\right). \tag{4}$$

Since the development of the effective width concept, experimental programs such as those by Pekoz [6] and Cohen and Pekoz [7] have been performed on stiffened plates to determine the effective width equations for stiffened elements under pure compression and stress gradients. Due to the complexities of testing unstiffened plates such tests had not been performed until recently [8], and until the latest editions of AS/NZS 4600 [9] and NAS [10] the effective widths of unstiffened elements under stress gradients were conservatively calculated by assuming the element was uniformly compressed. Rhodes [11] suggested that the post-buckling strength of unstiffened plates under stress gradients with compression at the unsupported edge had little post-buckling strength and the

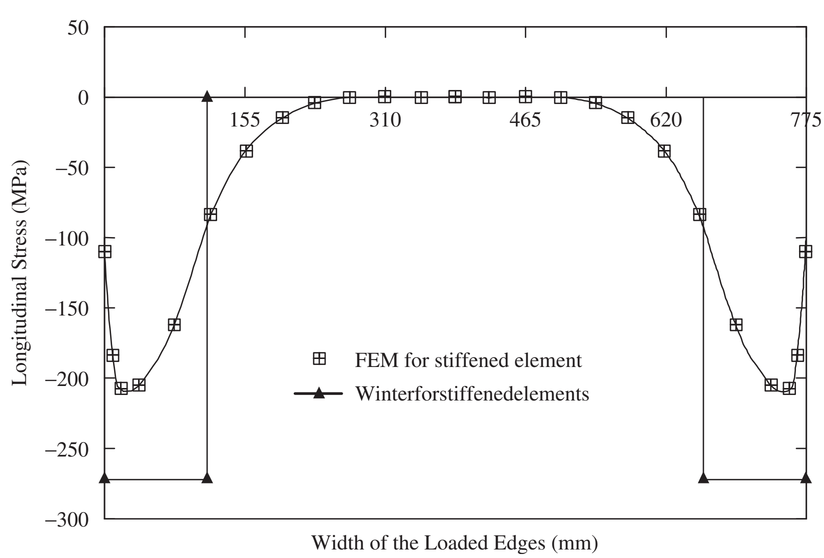

Fig. 3. Longitudinal stress at ultimate load for stiffened element of slenderness $\lambda = 5$ in compression.