Thin-Walled Structures 47 (2009) 109–119

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Elastic lateral buckling of simply supported LiteSteel beams subject to transverse loading

Cyrilus Winatama Kurniawan, Mahen Mahendran *

Faculty of Built Environment and Engineering, Queensland University of Technology, Brisbane, QLD 4000, Australia

ARTICLE INFO

Article history:
Received 27 March 2008
Accepted 20 May 2008
Available online 25 July 2008

Keywords:
LiteSteel beam
Lateral distortional buckling
Lateral torsional buckling
Transverse loading
Non-uniform moment distribution
Load height

ABSTRACT

The buckling strength of a new cold-formed hollow flange channel section known as LiteSteel beam (LSB) is governed by lateral distortional buckling characterised by simultaneous lateral deflection, twist and web distortion for its intermediate spans. Recent research has developed a modified elastic lateral buckling moment equation to allow for lateral distortional buckling effects. However, it is limited to a uniform moment-distribution condition that rarely exists in practice. Transverse loading introduces a non-uniform bending moment distribution, which is also often applied above or below the shear centre (load height). These loading conditions are known to have significant effects on the lateral buckling strength of beams. Many steel design codes have adopted equivalent uniform moment-distribution and load-height factors to allow for these effects. But they were derived mostly based on data for conventional hot-rolled, doubly symmetric I-beams subject to lateral torsional buckling. The moment-distribution and load-height effects of transverse loading for LSBs, and the suitability of the current design modification factors to accommodate these effects for LSBs are not known. This paper presents the details of a research study based on finite element analyses on the elastic lateral buckling strength of simply supported LSBs subject to transverse loading. It discusses the suitability of the current steel design code modification factors, and provides suitable recommendations for simply supported LSBs subject to transverse loading.

1. Introduction

LiteSteel beam (LSB) is a new cold-formed high-strength and thin-walled steel section developed by Smorgon Steel Tube Mills, using its patented dual electric resistance welding and automated continuous roll-forming techniques. This section has a unique mono-symmetric channel shape comprising two rectangular hollow flanges and a slender web (Fig. 1), and is currently being used as flexural members in the light industrial, commercial and domestic markets. The section depth and flange width of LSB sections vary from 125 to 300 mm (125, 150, 200, 250 and 300) and from 45 to 75 mm (45, 60 and 75), respectively. Flange height is one-third of the flange width for all sections, with their thicknesses varying from 1.6 to 3.0 mm (1.6, 2.0, 2.5 and 3.0). Available LSB sections are identified by the section depth, flange width and thickness, for example, $300 \times 60 \times 2.0$ LSB [1]. The nominal yield strength of web and flange elements of LSB sections are 380 and 450 MPa, respectively.

Recent research [2] has shown that the structural performance of LSBs for intermediate spans is governed by their lateral distortional buckling (LDB) behaviour as shown in Fig. 1(a). Under flexural action, the presence of two stiff hollow flanges and a slender web leads to this buckling mode, for which a web distortion occurs in addition to the lateral deflection and twist that occur in the common lateral torsional buckling (LTB) mode (Fig. 1(b)). This, therefore, reduces its buckling resistance to be lower than that based on LTB. Nevertheless, long-span LSBs are governed by LTB mode as for other open steel sections (Fig. 1(b)).

Mahaarachchi and Mahendran [2] have shown that the modified elastic lateral buckling moment equation developed by Pi and Trahair [3] to allow for LDB effects can be used adequately for LSB sections. However, this equation is limited to a uniform moment distribution condition that rarely exists in practice (Fig. 2). A transverse load on a simply supported beam introduces a non-uniform bending moment distribution, and is also often applied above or below the shear centre (load-height effect) as seen in Fig. 2. Accurate assessment of these loading conditions in design is important as they can significantly affect the lateral buckling strength of steel beams.

In the current steel design standards (i.e. Australian, American and British), a simple modification to the elastic lateral buckling moment equation with an equivalent uniform moment factor (moment modification) is used to accommodate the effects of non-uniform moment distribution, while a load-height factor (k_l)

* Corresponding author. Tel.: +617 38642543; fax: +617 38641515.
E-mail address: m.mahendran@qut.edu.au (M. Mahendran).

0263-8231/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tws.2008.05.012

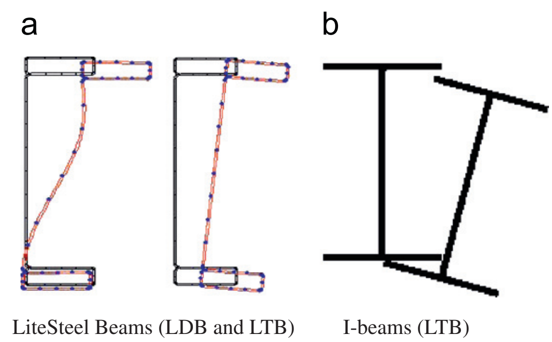

Fig. 1. Lateral buckling modes of beams. (a) LiteSteel beams (LDB and LTB) and (b) I-beams (LTB).

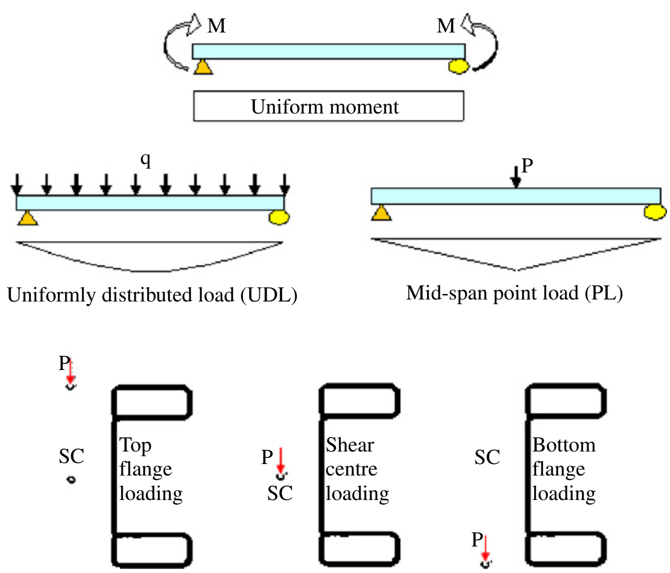

Fig. 2. Simply supported beam with various loading conditions.

is used in the determination of a modified effective length to allow for the effect of loading positions. But they were derived mostly based on the data for conventional hot-rolled, doubly symmetric I-beams subject to LTB. In contrast, LSBs are made of high-strength steel and have a unique mono-symmetric cross-section with specific residual stresses and geometrical imperfections along with a unique LDB mode. The moment-distribution and load-height effects of transverse loading for LSBs, and the suitability of the current steel design code methods to accommodate these effects for LSBs are not yet known. The research study presented in this paper was undertaken to investigate the effects of moment distribution and load height of transverse loading on the lateral buckling strength of simply supported LSBs. Two types of common transverse loading were considered, the uniformly distributed load (UDL) and the mid-span point load (PL) shown in Fig. 2. The quarter point loading (QL) was also considered in the moment-distribution study. Comparisons with the current steel design code modification factors were also made in order to make suitable recommendations for LSBs subject to transverse loading. This paper presents the details of this study and the results.

2. Current design codes

Tables 5.6.1 of Australian steel structures design code, AS4100 [4], provides the following equivalent uniform moment or moment modification factors (α_m) for beams subject to transverse loading.

$$\alpha_m = 1.13 \text{ for uniformly distributed load} \tag{1a}$$

$$\alpha_m = 1.35 \text{ for mid-span point load} \tag{1b}$$

Alternatively, AS4100 also allows a simple α_m approximation using Eq. (2) that applies to any bending moment distribution shown in Fig. 3. AS4100 Clause 5.6.3 allows the effect of load height by increasing the effective length with a k_l of 1.4 in calculating the elastic buckling resistance for top flange (TF) loading and 1.0 for bottom flange (BF) loading:

$$\alpha_m = \frac{1.7M_m^*}{\sqrt{[(M_2^*)^2 + (M_3^*)^2 + (M_4^*)^2]}} \leqslant 2.5 \tag{2}$$

where M_m is the maximum design bending moment in the segment. M_2, M_4 are the design bending moments at the quarter points of the segment and M_3 is the design bending moment at the midpoint of the segment.

American steel structures design code ANSI/AISC 360 [5] provides a general equation of moment modification factor (C_b) as given by Eq. (3) for various shapes of bending moment distributions (Fig. 3). This equation was originally developed by Kirby and Nethercot [6]. However, ANSI/AISC 360 does not provide any explicit provision to account for the load-height effect,

$$C_b = \frac{12.5M_{max}}{12.5M_{max} + 3M_A + 4M_B + 3M_c} \leqslant 2.27 \tag{3}$$

British steel structures design code BS5950-1 [7] provides a general equation of moment modification factor (m_{LT}) as given by Eq. (4) that is analogous to the AISC equation, which also applies to various shapes of bending moment distributions. The effect of load height when a load is applied at the TF is included by increasing the effective lengths by 20% (k_l of 1.2) in calculating the elastic buckling resistance. Otherwise the normal loading condition is assumed:

$$m_{LT} = 0.2 + \frac{0.15M_2 + 0.5M_3 + 0.15M_4}{M_{max}} \geqslant 0.44 \tag{4}$$

AS4100, ANSI/AISC 360, and BS5950-1 are hot-rolled steel structural design codes. The cold-formed steel structural design codes generally adopt the equivalent uniform moment factor used in the hot-rolled steel structural design codes although there is limited research in this area. Pi et al. [8] showed that moment modification factors in AS4100 are reasonably accurate (conservative) for cold-formed channel sections, while Pi and Trahair [3] demonstrated that they are adequate for cold-formed doubly symmetric hollow flange beams subject to LDB except for beams with low-modified slenderness. However, Pi et al. [9] reported that AS4100 modification factors are not accurate for cold-formed *Z*-sections. Kitipornchai et al. [10], Kitipornchai and Wang [11], Helwig et al. [12], and Lim et al. [13] also showed that the accuracy of moment modification factors varied depending on the

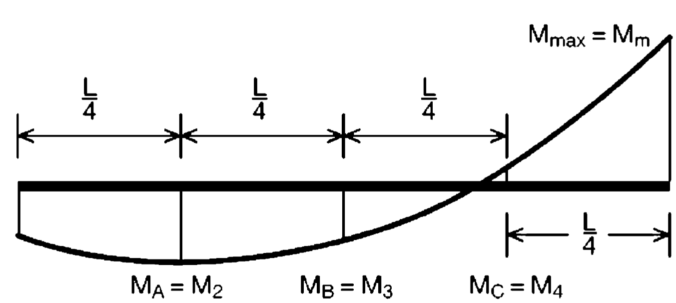

Fig. 3. Moment diagram for Eqs. (1)–(4).