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On the local buckling of RHS members under axial force and biaxial bending

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ABSTRACT

This paper presents the results of a large parametric study concerning the evaluation of the critical local buckling coefficient for thin-walled rectangular hollow section (RHS) members subjected to combined axial load and biaxial bending, accounting for web-flange interaction. The calculation of the half-wavelength leading to the minimum critical local bifurcation load is performed by means of a Generalized Beam Theory specialization, which makes it possible to quickly solve a large set of cases. In particular, taking advantage of the small half-wavelength of local buckling, it is assumed that the stresses are uniformly distributed along the member length, making it possible to resort to semi-analytical solutions using sinusoidal half-wave amplitude functions for the GBT cross-section deformation modes. On the basis of the results obtained, the key parameters governing local buckling are identified, leading to easy-to-use charts and closed-form formulae to determine the local buckling coefficient.

1. Introduction

Increasing demands for economical and sustainable structures are continuously fostering the use of more efficient structural members. The need to reduce material waste and the development of higher strength steel grades have paved the way for steel members with cross-sections exhibiting increasingly thinner walls, more prone to complex buckling phenomena. As a result, an accurate safety checking of these members requires an equally accurate prediction of the governing buckling phenomena, which is usually achieved by calculating (directly or indirectly) critical bifurcation loads.

In the particular case of rectangular hollow sections (RHS), the relevant buckling mode is local (plate-like), without displacements of the wall junctions. Most current steel design codes, in particular the European code [1], address this problem by assuming that each wall is hinged along the edges, meaning that it may buckle independently. Naturally, this approach is on the safe side for the governing wall, but it potentially constitutes a rough approximation, as the beneficial effect of the rotational restraint provided by the adjacent walls should be taken into consideration. In fact, the cross-sectional stress distribution and geometric ratios (e.g. the cross-section height/width) can lead to significant variations of the local buckling coefficient k_σ, defined through

$$\sigma_{cr} = k_\sigma \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 \quad (1)$$

where σ_{cr} is the critical stress, E is Young's Modulus, ν is Poisson's ratio, b is the relevant wall width and t is its thickness. For RHS of constant thickness, this coefficient can be related to the web ($b = h_w$) or to the flange $b = b_f$, i.e.,

$$\sigma_{cr} = k_w \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{h_w}\right)^2 = k_f \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b_f}\right)^2 \quad (2)$$

leading to

$$k_f = k_w\left(\frac{b_f}{h_w}\right)^2 \quad (3)$$

An accurate estimation of the buckling coefficient can only be achieved through numerical methods. Nowadays this can be done quite easily using freely available numerical tools such as GBTUL [2] or CUFSM [3], which explicitly account for the cross-section wall interaction.

Despite the relevance of determining accurate buckling coefficients for RHS members, not many studies are available. In [4] the effect of the flange-web interaction was assessed using an energy method and a deflection function with two coefficients per wall. The resulting buckling coefficients for an axially compressed tube were then plotted as a function of the cross-section mid-line width/height ratio and for flange/web thickness ratios of 0.5, 1 and 2. This problem is also addressed in [5,6], where the geometric proportions for which either the web or the flange drives cross-section buckling are approximately identified. More recently, in [7], extensive finite strip analyses were conducted on the

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AISC cross-section shapes database, with the objective of proposing analytical expressions for the local buckling coefficient for members subjected to either axial compression, major axis bending or minor axis bending.

A thorough search of the relevant literature showed that no results are available for RHS members under combined axial and biaxial bending. The work presented in this paper aims at filling this gap, by obtaining easy-to-use charts and closed-form analytical expressions for the local buckling coefficient of RHS members exhibiting a wide range of geometric configurations and load cases. To efficiently perform the calculations, a new numerical model based on the fundamental principles of the Generalized Beam Theory (GBT) is developed and employed. GBT is a thin-walled bar theory that handles cross-section in-plane and out-of-plane deformation through the consideration of so-called "cross-section deformation modes", whose longitudinal amplitude functions constitute the problem unknowns. GBT was introduced by Schardt [8] and has been continuously developed since then. Presently, its efficiency is well-established, due to its ability (i) to obtain accurate and structurally enlightening solutions with just a few deformation modes and also (ii) to include or exclude specific effects in a very straightforward manner (see, e.g., [9,10] and the list of publications by the Lisbon-based research group at www.civil.ist.utl.pt/gbt).

The outline of the paper is as follows. Section 2 describes the numerical model developed for the determination of the critical

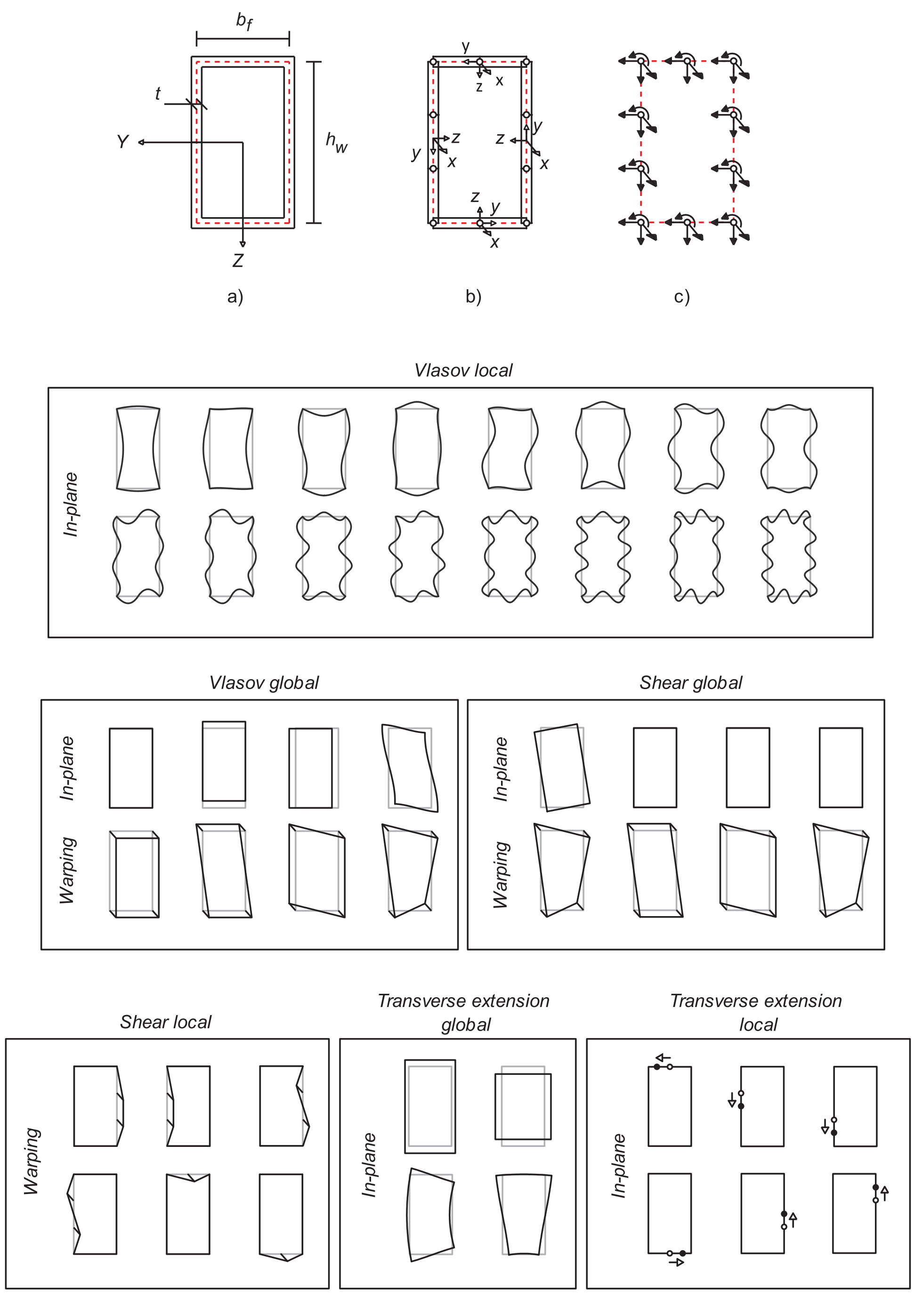

Fig. 1. a) Geometry b) discretization c) initial DOFs and d) Deformation mode space.