GBT-Based Computational Approach to Analyse the Geometrically Non Linear Behaviour of Steel and Composite Thin-Walled Members

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ABSTRACT

The Generalised Beam Theory (GBT), which extends Vlassov's classical beam theory in order to account for cross-section (local – flexural and distortional) deformations, has been shown to be a rather powerful, elegant and clarifying tool to investigate the local and global buckling (bifurcation) behaviour of thin-walled prismatic structural members. GBT was originally developed by Schardt (1983, 1989), about two decades ago and in the context of isotropic materials, and subsequently employed by Davies et al. (e.g., 1996, 1998) to study the stability behaviour of cold-formed steel profiles. Quite recently, Silvestre & Camotim (2001, 2002) have extended the available GBT to arbitrary orthotropic materials, thus enabling its application to either composite (FRP – fiber reinforced plastic) or laminated plate thin-walled members. Moreover, the last authors are presently working on a further extension of GBT, which aims at making it possible (i) to perform member local and global post-buckling analyses and also (ii) to take into account the influence of the initial geometrical imperfections.

Besides accounting for the cross-section in-plane (local) deformations, which requires the incorporation of genuine folded-plate theory concepts, the most relevant feature exhibited by GBT resides in the fact that it expresses the member deformed (buckling mode) configuration as a linear combination of a set of pre-determined cross-section fundamental deformation modes. Due to this unique feature, GBT offers possibilities, not available even through the use of powerful numerical techniques, such as the finite element (FEM) or finite strip methods. Indeed, it is fair to say that GBT has been established as a valid and often advantageous (mostly in terms of clarity) alternative to fully numerical analyses.

The steps and procedures involved in the application of GBT are associated to two main tasks, namely (i) a cross-section analysis (identification of the deformation modes and determination of the corresponding modal properties) and (ii) a member analysis (solution of the differential equilibrium equations and boundary conditions, for specific member end support conditions and loading). Concerning the first task, the use of symbolic computation procedures has proven to be significantly more efficient than the standard numerical techniques. As for the second task, more commonly performed in structural analysis problems, a rather general FEM formulation has been developed by Silvestre & Camotim (2002), which can readily be applied to arbitrary isotropic or orthotropic members and is able to take into account any specified number of deformation modes. In a few special cases (of considerable practical interest, though), analytical expressions can also be obtained through the adequate use of symbolic computation.

The main objectives of this lecture are the following: (i) to provide an overview of the GBT fundamentals, field of application and recent developments, (ii) to address the most relevant issues related to the computer implementation of GBT buckling and post-buckling (geometrically non linear) analyses, which is achieved through a combination of symbolic computation procedures and FEM incremental-iterative techniques, and (iii) to present and

discuss some numerical results, concerning the behaviour of several cold-formed steel and composite thin-walled members, selected in order to enable a proper illustration and assessment of the elegance, efficiency and capabilities of GBT.

Keywords: Generalised Beam Theory (GBT); Thin-walled members; FEM implementation; Stability behaviour; Post-buckling behaviour