Composite Structures 113 (2014) 236–248

Contents lists available at ScienceDirect

Composite Structures

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

Local buckling of shear-deformable laminated composite beams with arbitrary cross-sections using discrete plate analysis

Torsten Kuehn [a], Hartmut Pasternak [b], Christian Mittelstedt [c,*]

[a] EADS EFW – Elbe Flugzeugwerke, Grenzstr. 1, D-01109 Dresden, Germany
[b] Brandenburgische Technische Universität Cottbus, Department of Civil Engineering, Chair of Steel and Wooden Constructions, Konrad-Wachsmann-Allee 2, D-03046 Cottbus, Germany
[c] SOGETI High Tech GmbH, Hein-Sass-Weg 30, D-21129 Hamburg, Germany

ARTICLE INFO

Article history:
Available online 25 March 2014

Keywords:
Buckling
Laminates
Thin-walled
Webs
Flanges
First-order shear deformation theory

ABSTRACT

The present paper deals with the onset of local buckling of compressively loaded thin-walled beams made of orthotropically laminated composite materials using discrete plate analysis. The analysis model focusses on the buckling of webs and flanges of composite beams with arbitrary cross-sections under uniform longitudinal compressive load. In order to account for transverse shear deformations as they are typical for moderately thick to thick laminated composite materials made of e.g. carbon fibre reinforced plastics, the present analysis is based on first-order shear deformation theory, thus employing the classical Reissner–Mindlin plate theory for the analysis of laminated composite structures. The idealisation consists of modelling the webs as being simply supported at all four edges, while at the longitudinal unloaded edges an elastic clamping is assumed which is represented by a clamping stiffness that takes material, geometry and layups of the adjacent flanges of the beams into account. Accordingly, the flanges are treated as plates with three simply supported edges and one free edge, wherein the unloaded simply supported edge is elastically clamped in order to represent the rotational support by the adjacent web. The analysis of the web and flange buckling loads is performed using the Rayleigh–Ritz-method employing specifically chosen shape functions for the out-of-plane displacements and the rotations of the cross-sections. The accuracy of the employed approaches is established by comparison with accompanying finite element simulations of actual thin-walled composite beams. It is revealed that the presented methodology is highly efficient in terms of computational effort and yet performs with satisfying accuracy which makes it very attractive for actual practical applications whenever the local stability behaviour of composite beams is to be considered.

© 2014 Elsevier Ltd. All rights reserved.

1. Structural situation and idealisation

Thin-walled structures made of laminated composite materials are increasingly used in many engineering branches, especially for all application purposes where the weight of the structure is a significant factor to be considered in the analysis and design of structural members. Traditionally, structures made of composite materials are ideal candidates for lightweight engineering purposes, but have also found an increased use in civil engineering, e.g. in the form of reinforcements or as complete load-bearing beam structures made of laminated composite materials, for example for application in bridge constructions (see, among others, [44,39,38,37,21,15,43,12,22,35]). Naturally, due to their thin-walled nature, beam structures are prone to buckling failure (see Fig. 1.1 for two exemplary beam structures under compressive load), where the buckling behaviour may consist of a local, a global or an interactive form.

While the global and local stability behaviour of beam structures made of classical isotropic civil engineering materials like steel is rather well understood (see for instance the classical textbook by [41]), there are still many open questions to be resolved when the buckling behaviour of beams made of anisotropic composite laminated materials is to be investigated. These questions may refer to the purely global buckling behaviour (i.e. Euler-type buckling or flexural–torsional buckling, see for example the works by [6,9,46,14,13,33,36]) as well as to the local buckling of flanges and webs of the beam (cf. the works by [1,7,24,25,30,45,47]), wherein in the vast majority of investigations that are available

* Corresponding author. Tel.: +49 1735120376.
E-mail addresses: torsten.kuehn@efw.eads.net (T. Kuehn), hartmut.pasternak@tu-cottbus.de (H. Pasternak), christian.mittelstedt@sogeti-hightech.de (C. Mittelstedt).

http://dx.doi.org/10.1016/j.compstruct.2014.03.022
0263-8223/© 2014 Elsevier Ltd. All rights reserved.

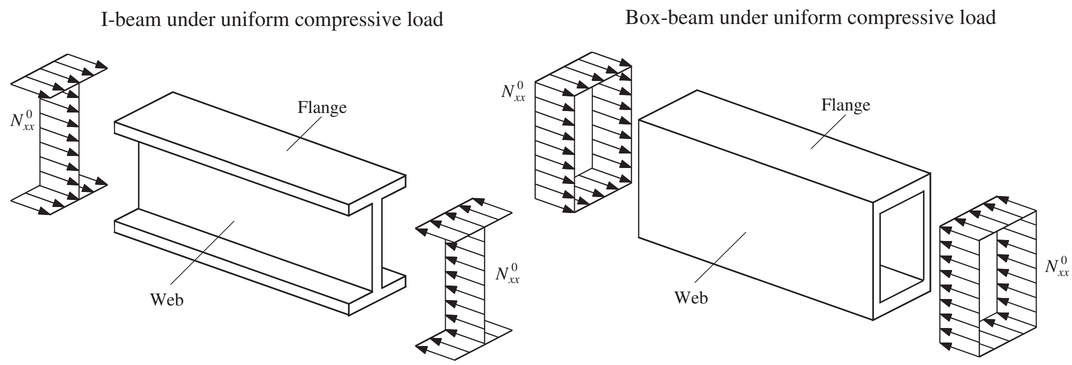

Fig. 1.1. I-beam and box-beam under uniform compressive load.

for the local buckling behaviour, a discrete plate analysis approach has been employed. In this context, discrete plate analysis means that both the webs and the flanges are treated as separate plates cut away from the beam cross-section, where at the junctions between webs and flanges elastic restraints are considered that represent the geometry, material properties and layups of the adjacent beam members (see Fig. 1.2). However, in many situations local and global may occur simultaneously which is generally referred to as interactive buckling (see e.g. [10,8,17,5,3,4,23]).

Concerning the local buckling behaviour of flanges and webs of composite beams and especially the development of closed-form analytical methods for the rapid analysis and sizing of such beam

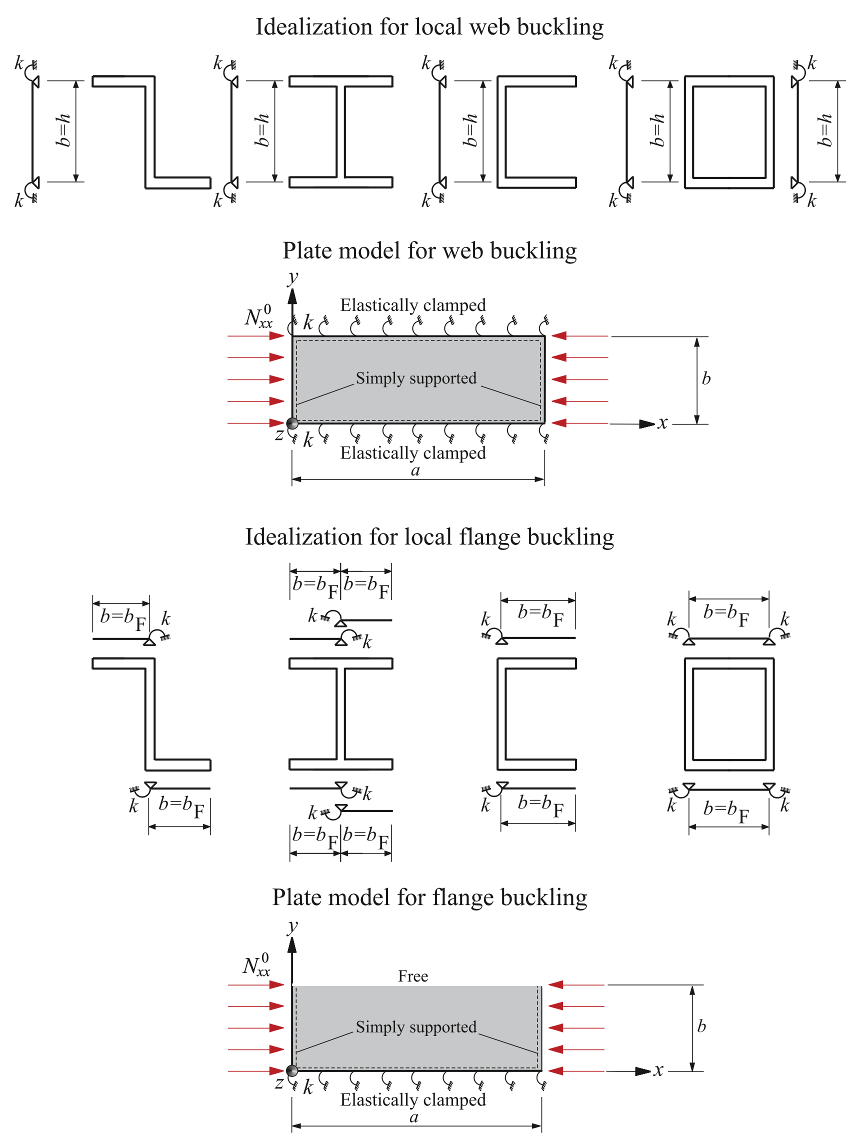

Fig. 1.2. Idealisation of webs (upper part) and flanges (lower part) in the framework of discrete plate analysis.

Download English Version:

https://daneshyari.com/en/article/251586

Download Persian Version:

https://daneshyari.com/article/251586

Daneshyari.com