Accepted Manuscript

A composite beam element with through the thickness capabilities based on global-local superposition

André Lima, Alfredo Faria

PII: S0263-8223(17)32968-9
DOI: https://doi.org/10.1016/j.compstruct.2017.11.051
Reference: COST 9117

To appear in: *Composite Structures*

Received Date: 12 September 2017
Revised Date: 13 November 2017
Accepted Date: 20 November 2017

Please cite this article as: Lima, A., Faria, A., A composite beam element with through the thickness capabilities based on global-local superposition, *Composite Structures* (2017), doi: https://doi.org/10.1016/j.compstruct.2017.11.051

A composite beam element with through the thickness capabilities based on global-local superposition

André Lima[a,*], Alfredo Faria[a]

[a] Department of Mechanical Engineering, Instituto Tecnológico de Aeronáutica (ITA), Praça Marechal Eduardo Gomes, 50, São José dos Campos, SP 12228-900, Brazil

E-mail adresses: andresl@ita.br (A. Lima), arfaria@ita.br (A. Faria).

Abstract: A beam element is proposed that captures through the thickness effects in composite laminated beams, namely, transverse shear and normal stresses and strains. Stress continuity along the thickness is inherently enforced leading to a system of algebraic equations that is solved in the element level, permitting independence between the number of layers and the number of degrees of freedom, with all of them possessing a clear physical significance. Global-local superposition is performed in the thickness direction, where a cubic global displacement field, that guarantees imposition of the boundary conditions at the top and bottom surfaces of the beam, is combined with a layerwise linear local displacement distribution that assures zig-zag behavior of the stresses and displacements. The element behavior for different length-to-thickness ratios is assessed and compared to the analytical elasticity solution, as well as a commercial finite element alternative.

Key-words: composite beam; through the thickness effects; zig-zag; global-local superposition.

Funding: This work was funded by the Brazilian agencies CAPES grant 1642839; CNPq grant 300886/2013-6.

Introduction

The application of multilayered structures has increased in many fields of engineering, accompanied by a burst in the number of theories and models to represent their behavior. The main reason driving that burst was the inability of classical theories of beams, plates and shells [1–4] to reproduce piecewise continuous displacement fields and transverse shear stress fields in the thickness direction [5]. Those theories also neglect transverse normal stresses, that are fundamental in failure analysis of multilayered structures (e.g., delamination).

This piecewise form of displacement fields and transverse stresses is often described in the open literature as zig-zag (ZZ), and the theories that describe this behavior, as well as interlaminar continuity (IC), are called Zig-Zag theories [6]. Those two effects are summarized by the acronym C^0_z requirements, meaning that displacements and transverse stresses must be C^0 continuous functions in the thickness direction.

[*] Corresponding author.