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# Assessment of various kinematic models for instability analysis of sandwich beams

Heng Hu [a], Salim Belouettar [b], Michel Potier-Ferry [c], Ahmed Makradi [b], Yao Koutsawa [b,*]

[a] School of Civil Engineering, Wuhan University, 8 South Road of East Lake, Wuchang, 430072 Wuhan, PR China

[b] Centre de Recherche Public Henri Tudor, 29, Avenue John F. Kennedy, L-1855 Luxembourg, Luxembourg

[c] Laboratoire d'Étude des Microstructures et de Mécanique des Matériaux, LEM3, CNRS, Université Paul Verlaine - Metz, Ile du Saulcy, 57045 Metz, France

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ABSTRACT

The aim of this paper is to present and compare various one-dimensional (1D) finite element (FE) models which are based on different kinematic models. The kinematic models presented take into account thickness variations, but differ in the inclusion of the shear deformation effects in their kinematics formulations. These 1D FE models are used to study global and local instability phenomenon in sandwich beams. Simulations of the buckling and three-point bending tests are performed to verify the capability of each model to reproduce the linear and nonlinear mechanical response of sandwich beams. The predicted results using 1D FE models are compared to a two-dimensional (2D) FE analysis, which is considered as a reference solution.



## 1. Introduction

Sandwich structures consist of a soft layer sandwiched between two thin stiff layers. These lightweight layered-like structures offer high mechanical performances such as high flexural stiffness, and they can support tensile and bending loads. However, under compressive loading, sandwich structures show local and global geometrical instabilities, which are of major concern in designing sandwich-based industrial components. To take into account both local and global instabilities, different kinematic models have been proposed that allow for the thickness variation along the sandwich cross-section. These models differ in the inclusion of effects of the shear deformation in their kinematics formulations. The model from [1] is able to predict both local and global instabilities naturally. This modeling considers two primary hypotheses: (i) the shear stress is constant in the core along the transversal direction; (ii) there is no shear stress in the top and the bottom skins. This kinematic model has been used recently by Hu et al. [2] to develop a one-dimensional (1D) finite element (FE) model to predict the global and local buckling of sandwich beams. In line with Léotoing et al. [1], Klug and Sun [3] and Smith and Teng [4] proposed a kinematic model with the same formulation for the top and bottom skins, but a simpler one for the core. In this modeling, the core transversal and longitudinal displacements are taken to be linear along the sandwich cross-section. Relative to both models cited above, Pandit [5] proposed a highly enriched kinematic model for both the skins and the core. In contrast to the models in [1,3,4], Pandit [5] does not neglect the shear stress in the top and bottom skins and also considers the continuity of the shear stress through the sandwich interfaces. For more details regarding refined beam theories, the interested reader can refer to the very recent work by Carrera and Giunta [6].

The aim of this paper is to study geometrical instabilities in a sandwich beam under compression and three-point bending tests, by using the three kinematic models cited above in conjunction with a 1D FE model. The capability of each model is validated using a two-dimensional 2D FE analysis, which is considered as a reference solution.

## 2. Kinematics and finite element formulations

Sandwich structures are considered to be plane and two-dimensional with a soft core and stiff skins, as shown in Fig. 1. Let $x$ and $z$ be the longitudinal and the transversal coordinates. $h_f$, $h_c$ and $h_t$ are respectively the thickness of the faces (skins), the thickness of the core and the sandwich beam total thickness. The length and the width of the sandwich beam are denoted respectively $l$ and

* Corresponding author. Tel.: +352 54 55 80 879; fax: +352 42 59 91 333.
*E-mail address:* yao.koutsawa@tudor.lu (Y. Koutsawa).

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