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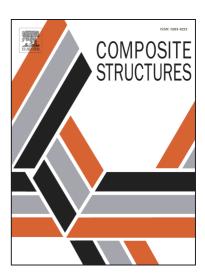
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# Use of higher-order Legendre polynomials for multilayered plate elements with node-dependent kinematics

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#### Abstract

In the present work, higher-order Legendre polynomials are adopted as shape functions of p-version plate finite elements (FEs) and used in combination with node-dependent kinematics (NDK) to construct computationally efficient global-local FE models for the analysis of multilayered plates. The use of higher-order Legendre polynomials enables the elements to accommodate the complex structural deformations with a fewer number of variables in the FE model. Derived from Carrera Unified Formulation (CUF), NDK can integrate plate kinematics based on Equivalent Single Layer (ESL) models and Layer-wise (LW) models to obtain global-local models using no ad hoc coupling. The combination of Legendre-type shape functions and NDK shows excellent rates of convergence, which can lead to FE models with high accuracy in the refined local area with a reduction in the computational efforts. The capabilities of the proposed approach are investigated through various numerical examples by comparing the solution accuracy versus the computational expenses.

Keywords: laminated plate, Carrera Unified Formulation, Legendre polynomials, node-dependent kinematics, finite element

#### 1. Introduction

- 2 Composite laminated structures have attracted significant attention in the engineering field in the recent
- decades due to their outstanding structural efficiency. Due to the complex arrangement of these materials,
- conventional simulation tools soon reach their limits, which has boosted the demands for structural analysis
- 5 methods to capture their mechanical responses accurately.
- Towards the accurate analysis of thin-walled laminated structures, a variety of 2D theories have been
- 7 proposed and extensively implemented in numerical models. Classical Plate Theory (CPT) [1] is the simplest
- <sup>8</sup> 2D model, which is based on Kirchoff-Loves hypothesis. First-order Shear Deformation Theory (FSDT)
- [2] takes the transverse shear effects into account but can only approximate the shear stresses through the
- thickness of a plate as constants. A series of Higher-Order Theories (HOT) [3, 4, 5] have been suggested to
- improve the solution accuracy. Following this line, Carrera Unified Formulation [6] was introduced to derive
- <sup>2</sup> refined plate and shell models for the analysis of laminated thin-walled structures. Various theories can be
- integrated to formulate refined kinematics based on either Equivalent Single Layer (ESL) or Layer-wise (LW)
- <sup>14</sup> approach through the arbitrary sets of thickness functions. By making use of the so-called Fundamental
- Nucleus (FN), the corresponding governing equations can be derived in a unified and compact form [7]. In the
- 16 CUF framework, a variety of 2D models constructed with different kinematic assumptions were introduced in
- the last years by Cinefra and Valvano [8], Cinefra et al. [9, 10, 11] and Carrera et al. [12].

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