Summary

The correct calculation of displacements and stresses is of paramount importance in modern engineering approaches. At the same time, it is crucial to save computational time and find the most efficient finite element models.

In this thesis, a general method to build both beam and plate/shell models in a coherent formulation is presented. This method starts from the concepts proposed in the works related to the Carrera Unified Formulation (CUF), and then its capabilities are enhanced to permit independent expansion for each displacement component. The CUF is used to describe the kinematics of cross-sections in beams and thickness-lines in plates and shells. In this study, the theories are constructed Taylor- and Lagrange-based expansions over these cross-sections and thickness lines. Furthermore, the present method is able to be used in the same structure theory, the Equivalent Single Layer and the Layer-Wise approaches, which can be called mixed ESL/LW models. The finite element method is applied to discretize structures along the beam axis or the mid-surface for plates and shells. Using the principle of virtual displacements, governing equations are derived for linear mechanical cases. The methodology is validated through case studies involving beams, plates, and shells, drawing examples from existing literature.

The thesis also introduces the Asymptotic-Axiomatic Method, a technique used to evaluate structural theories based on their accuracy and computational efficiency for specific problems. Unlike past works that used penalization techniques to develop models, this work proposes a new method for constructing finite element matrices with consistent degrees of freedom. Key results include the creation of best theory diagrams and the assessment of a model relative to a reference solution. This work also introduces the concept of Node-Dependent Kinematics in beam formulation, enabling the use of distinct expansions for each displacement variable and FE node. This method is particularly interesting for the study of thin-walled structures. Local kinematic refinements can be applied without modifying the existing FE mesh, and the approach eliminates the need for additional coupling or superposition techniques in the FE matrices.

Following the study of structures under pure mechanical loads, the plate formulation is extended to thermal decoupled analyses. The method has demonstrated efficiency for both isotropic and composite materials.

Finally, the complete mathematical nonlinear Unified formulation is developed for beam composite structures. As is customary, each displacement component can adopt a distinct model independent of the others. One of the most interesting outcomes is that, at each equilibrium point, the relative importance of the terms changes, requiring adjustments to select the most accurate models based on the specific conditions.