CERIS Civil Engineering Research and Innovation for Sustainability

Towards a more efficient modelling of thin-walled structures: combining beam finite elements with deformable cross-section and shell finite elements

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Summary

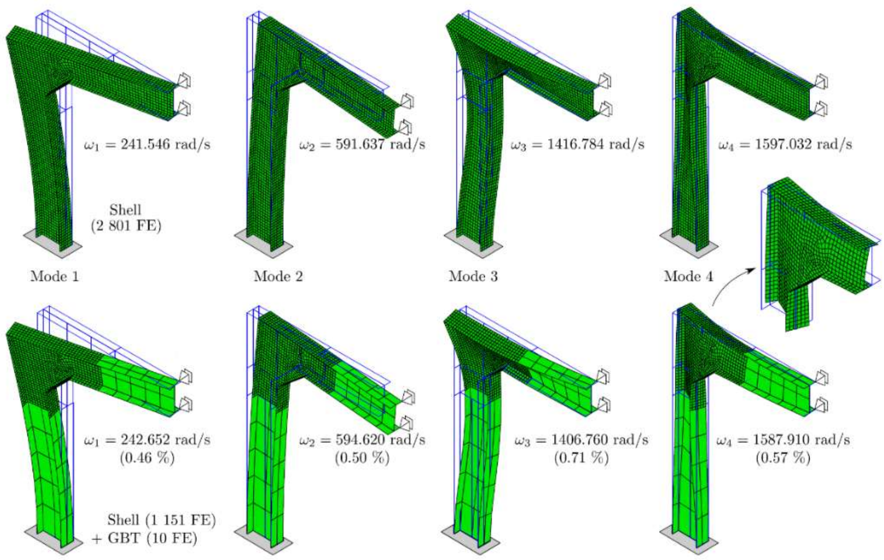
In this thesis, computationally efficient strategies to model thin-walled structures are developed, implemented, validated and applied, combining the advantages of beam finite elements that include cross-section deformation — understanding the mechanical behaviour, from the modal decomposition of the solution into "cross-section deformation modes", which have a clear structural meaning — and conventional shell finite elements — versatility and reduced computational effort in non-linear problems. The cross-section deformation modes are obtained from the Generalised Beam Theory (GBT). Two approaches are explored: (i) the combination, in the same model, of beam finite elements including cross-section deformation (using the GBT deformation modes) and shell finite elements (the MITC-4 element was chosen) and (ii) the recovery of the GBT deformation mode participations through post-processing shell finite element model results. In both cases, several types of analyses are considered: geometrically linear (elastic, elastoplastic and dynamic) and geometrically non-linear (linear stability, vibration and elastic/elastoplastic with large displacements/finite rotations).

In the first approach, the beam finite elements are used in the elastic and prismatic zones, as well as in zones requiring the consideration of a reduced number of deformation modes, while shell elements are employed in the remaining zones. It is shown that this approach leads to a significant computational efficiency (compared to models involving only shell finite elements) in the whole range of analyses considered, even if, in some cases, it is necessary to carry out an adaptive mesh refinement.

The second approach is useful when beam finite elements including cross-section deformation cannot be used or its use is not advantageous in terms of computational effort. It should be noted that, since its implementation in existing finite element programs (namely in commercial programs) is relatively straightforward, this approach has a great potential of application in structural design, enabling the reinterpretation of the results obtained in the light of GBT.

Keywords

Thin-walled structures, beam finite elements including cross-section deformation, shell finite elements, beam and shell finite element combination, Generalised Beam Theory (GBT), linear and non-linear analyses, stability and dynamic analyses.



L-shaped frame with a tapered joint: first four vibration modes obtained with a full shell model (top) and a beam-shell model (bottom).