CERIS Civil Engineering Research and Innovation for Sustainability

Generalised Beam Theory formulations for thin-walled bars with curved axis

Summary

In this thesis, Generalised Beam Theory-based (GBT) formulations are developed, implemented (through the finite element method) and validated, aiming at modelling, rigorously and efficiently, the linear and geometrically non-linear behaviour of pre-curved and/or pre-twisted thin-walled bars. It is shown that the proposed finite elements constitute a reliable alternative to shell finite element models, as they allow a better interpretation of the structural behaviour and involve a reduced computational effort.

This work was developed in two phases. First, an extension of the classic GBT (for straight bars) was developed to study the linear behaviour of bars with circular axis. This formulation (i) allows for the analysis of any type of cross-section (with straight walls), a task that required developing procedures to calculate the cross-section deformation modes that are dependent on the curvature radius, and (ii) recovers the classic equations of the Winkler and Vlasov theories. A displacement-based and a mixed displacementstrain-based finite element were developed. The mixed element is capable of eliminating all locking phenomena which arise in the displacement-based one.

Second, a geometrically exact formulation was developed for thin-walled bars with deformable cross-section and arbitrary initial configurations. This contribution allows studying problems where the initial configuration of the bar is curved and/or twisted and involving large displacements, finite rotations, and cross-section deformation.

The numerical examples shown throughout the thesis show that the proposed formulations lead to very accurate results using a reduced number of degrees-of-freedom (finite elements and deformation modes).

Keywords

Curved and twisted bars, thin-walled bars, Generalised Beam Theory (GBT), cross-section deformation, finite rotations, geometrically exact formulations.

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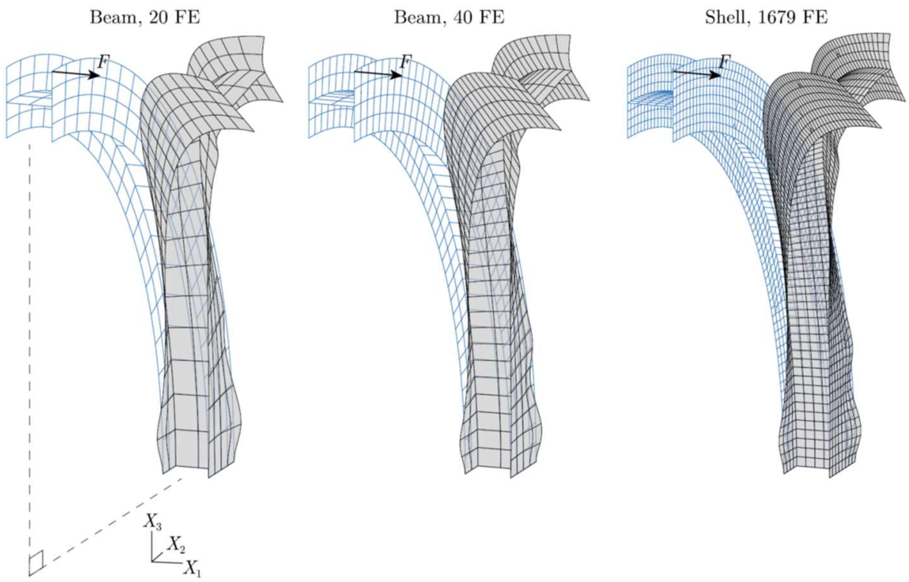

90◦ short arch with slender cross-section: deformed configurations obtained with beam (left, center) and shell (right) finite elements.