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3D stress analysis for complex cross-section beams using unified formulation based on Serendipity Lagrange polynomial expansion

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With available analytical approach it is difficult to accurately measure the 3D stress distribution in complex cross-section beams. The validity of analytical models is limited by assumptions of material heterogeneity, geometric dimensions and slenderness, and by Saint-Venant's Principle, i.e. they are only applicable to regions remote from boundary constraints, discontinuities and points of load application. Finite element methods are mostly used for analysing such problems but are computationally expensive. Alternatively, to capture localised three-dimensional stress fields analytically, displacement based high-order models are usually employed [1].

In the present work, a unified formulation approach based on a Serendipity Lagrange (SL) expansion model has been used to capture three dimensional (3D) stress distribution in T- section beams. The unified formulation developed by Carrera et al. [2] offers a computationally acceptable means of capturing high-fidelity 3D stress fields and provides one-dimensional (beam) theories that extend beyond classical theories by expressing the displacement fields over the cross-section in terms of higher order expansion functions. The resulting one dimensional finite elements that can be developed from the unified formulation have enhanced capabilities because they can obtain results that are usually provided by 3D elements with much lower computational cost. To capture localised 3D stress fields, displacement based higher-order models are required. Due to the hierarchical nature of SL expansion polynomials a high level of accuracy can be achieved by tuning the order of expansion, which is a free parameter of the model. The advantages of using unified formulation based on SL expansion over Taylor and Lagrange type models for various cross-section beams are discussed in the present study. Also, the results obtained show excellent agreement with 3D finite element solution performed in ANSYS.

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