University of BRISTOL
Bristol Composites Institute

Engineering and Physical Sciences Research Council

SECOND-ORDER HOMOGENISATION OF 3D WOVEN COMPOSITES USING SHELL ELEMENTS

Athira Anil Kumar, Aewis K. W. Hii, Bassam El Said, Stephen R. Hallett

3D woven composites have become increasingly popular due to improved mechanical properties, near net shape and reduced manufacturing costs. However, their internal architecture presents complex challenges in the computational modelling, with multiple length scales. In order to tackle this problem, users are employing computational homogenisation techniques to address the impracticality of high-fidelity (HF) models. The classical first-order homogenisation framework (1OH), although well-established, fails to properly capture the complex coupling (extension-bending) observed in woven composites. The higher-order deformation modes, such as bending and twisting, along with the effects of strain localisation from the structural model can be accounted for in a second-order homogenisation (2OH) scheme. This work focuses on implementing a second-order thick shell homogenisation framework[1] for woven composites and comparing the results with 1OH and high-fidelity models.

Homogenisation Frameworks

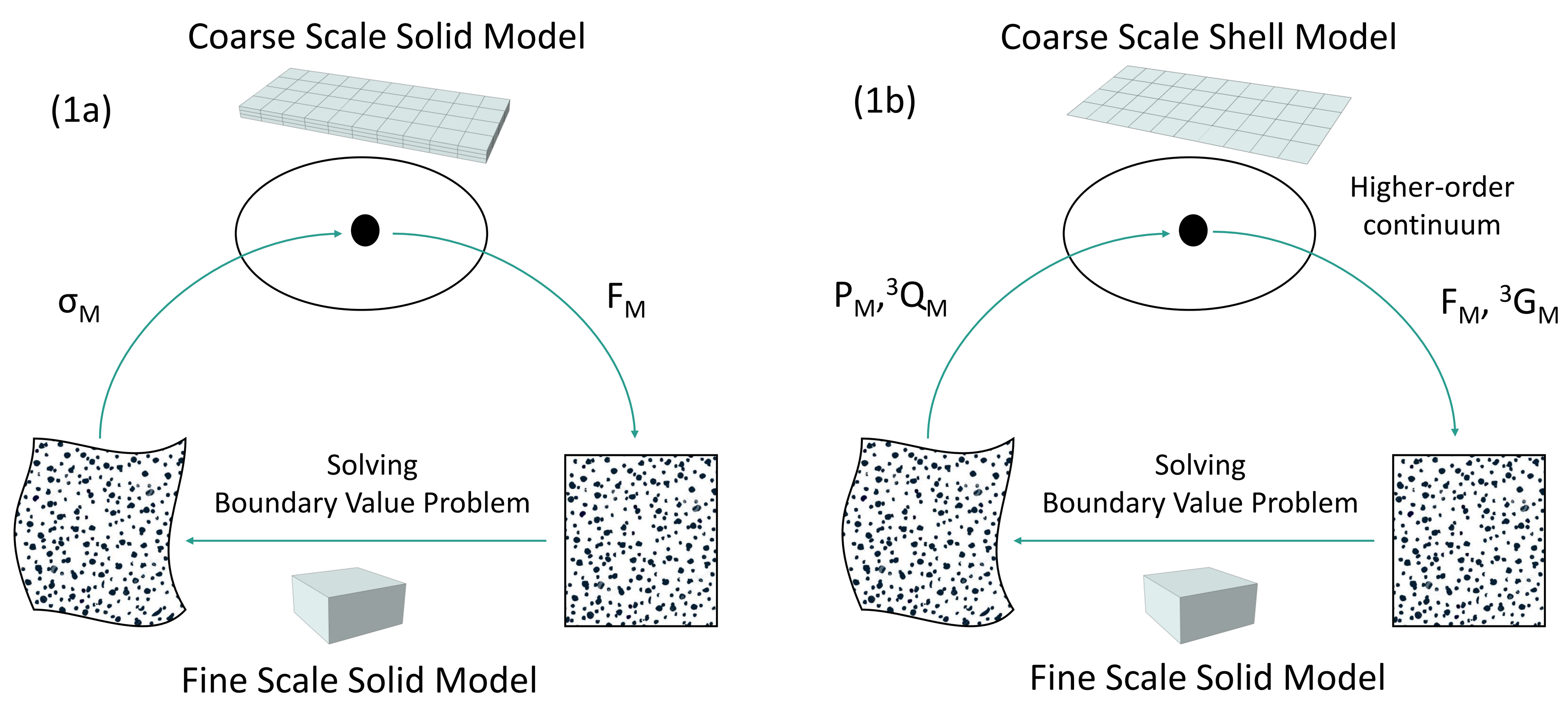

Figure 1: (a) First-order, and (b) second-order computational homogenisation framework

Code Integration Study

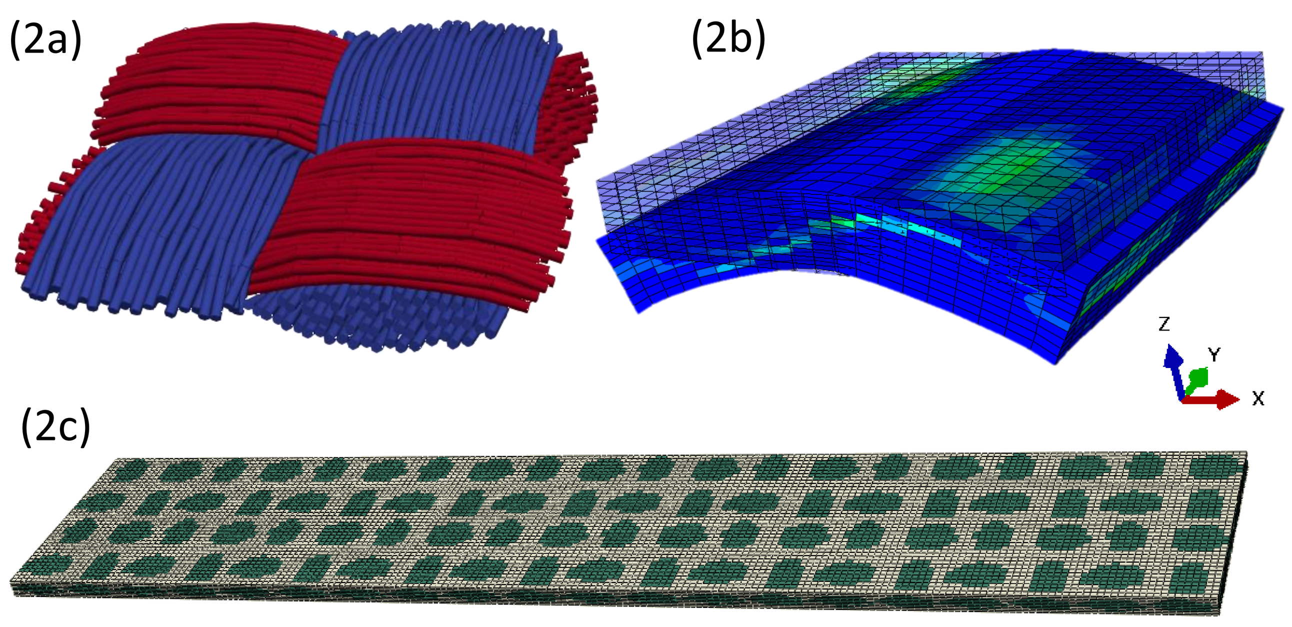

Figure 2: (a) Plain weave simulation and compaction,
(b) Meso-scale RVE undergoing bending,
(c) Tessellated high-fidelity macroscale model

Comparative Study

High Fidelity Model

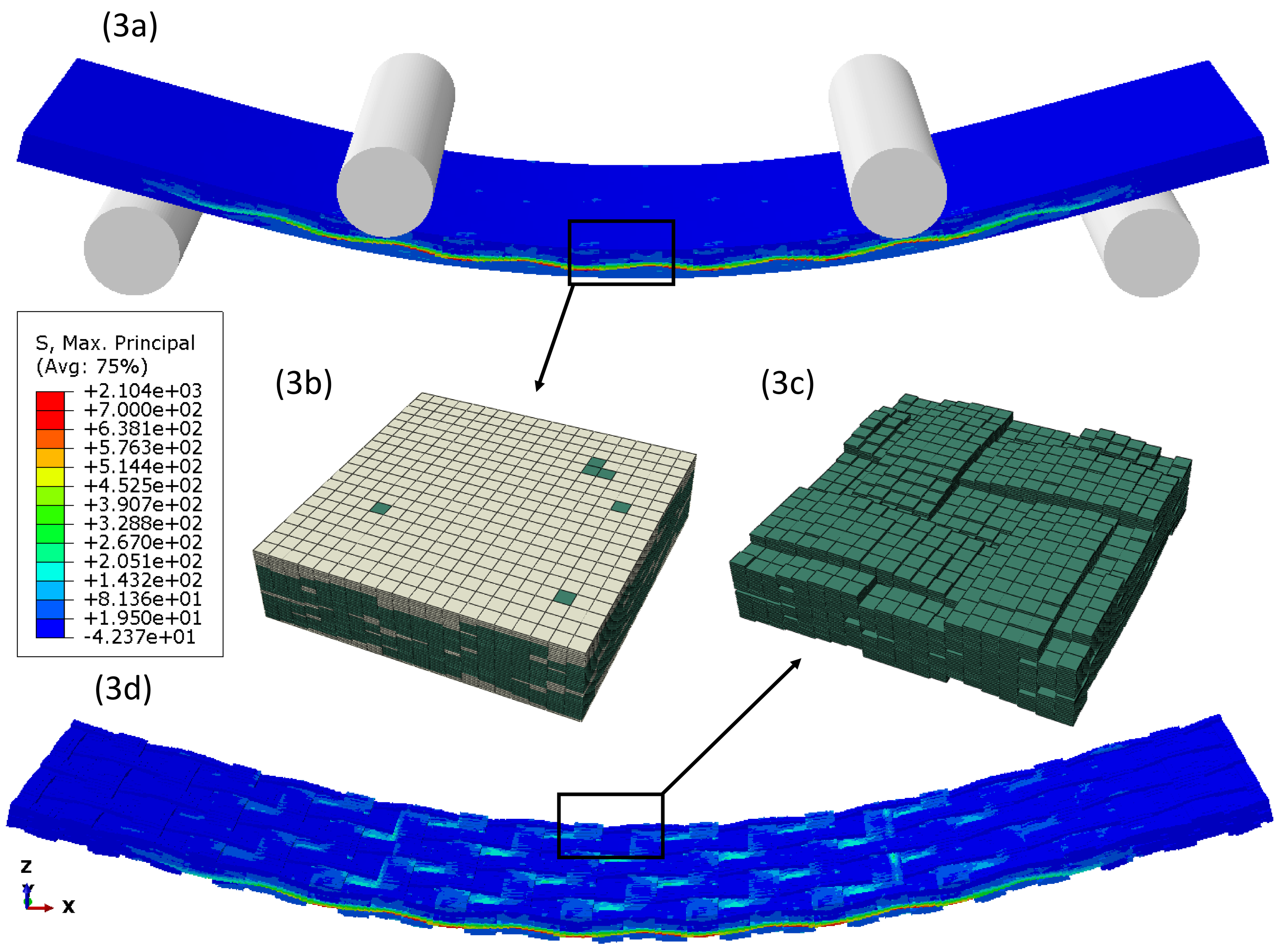

Figure 3: (a) Four-point bending (4PB) test set-up
(b) multi-layer plain weave RVE and, (c) the corresponding yarn elements
(d) 4PB response of a high-fidelity multi-layer plain weave model (yarn elements)

Results

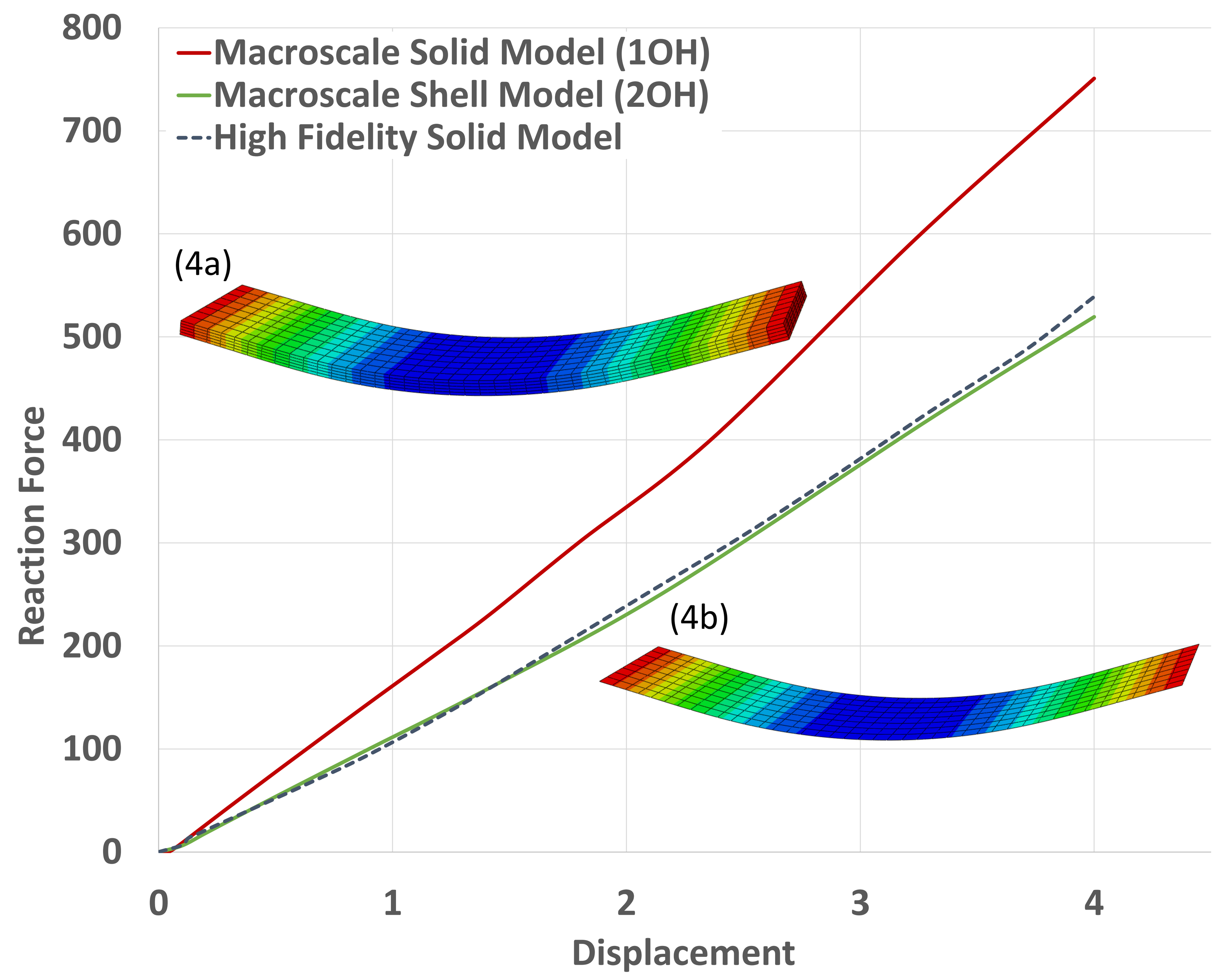

Figure 4:Four-point bending responses of macroscale solid model (1OH), macroscale shell model (2OH), and high-fidelity solid model. The bending deformation of (a) 1OH and (b) 2OH macroscale models are shown.

Future Work

- Obtain results for 4-point bending test simulation for 3D woven composites.
- Development of a second-order homogenisation framework using solid elements.
- Explore the use of machine learning (ML) techniques to replace the fine-scale analysis with an ML model.

[1] Aewis K.W. Hii, Bassam El Said, A kinematically consistent second-order computational homogenisation framework for thick shell models, Computer Methods in Applied Mechanics and Engineering, Volume 398, 2022.

bristol.ac.uk/composites

supported by