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FAILURE DETECTION IN MASONRY SHELLS HOMOGENISATION AND ITS INCORPORATION IN COUPLED TWO-SCALE COMPUTATIONS

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ABSTRACT

The formulation of macroscopic constitutive laws for the behaviour of masonry is complex, due to its strongly heterogeneous microstructure which considerably influences its failure behaviour. Due to the quasi-brittle nature of its constituents, this results in initial and damage-induced (evolving) anisotropy properties, accompanied with localisation of damage. In its structural use, such a material may be subjected to cracking, leading to localisation of damage at both the structural and constituents scales. Closed-form laws have therefore been developed for equivalent anisotropic media and applied for the modelling of plate failure [1]. As a complementary approach to closed-form constitutive relations, the multi-scale computational strategies aim at deducing a homogenised response at the structural scale from a representative volume element (RVE), based on constituents properties and averaging theorems. Homogenisation approaches allow to compute evolving homogenised continuum properties from the constituents constitutive behaviour of a heterogeneous mesostructure. In a nested computational procedure, in each point of the structural scale, a sample of the mesostructure is used to determine the material response. The local macroscopic strain measure is applied in an average sense to the sample and the resulting mesostructural stresses are determined numerically. The averaging of these mesostructural stresses and the condensation of the mesostructural tangent stiffness to the homogenised tangent stiffness then furnish the macroscopic material response associated with the macroscopic point. In addition to a fine scale constitutive description for the constituents, the definition of such a nested scheme essentially requires the choice of a structural scale representation allowing to model localisation of damage, and the set-up of scale transitions able to detect the onset of such localisation.

For in-plane loaded structures, in which both fine and coarse scale descriptions follow similar kinematical assumptions, these adaptations have been proposed recently in [2]. This approach can be extended to shell formulations, where higher order kinematical quantities such as curvatures appear at the structural scale. This requires adaptations of the structural scale description as well as of the scale transitions. A scale transition for homogenisation towards a Kirchhoff-Love shell behaviour was recently proposed in [3], based on a periodicity assumption. The constituents inside the unit cell may be modelled using any closed-form formulation. The mortar joints are represented here using cohesive zones equipped with a

Mohr-Coulomb criterion and the bricks are assumed to have a linear elastic behaviour. The detection of the structural scale localisation can be based on the acoustic tensor concept extended to the shell description [4]. This tensor has to be constructed based on the homogenised stiffness such that the localisation detection takes into account the coupling of flexural and membrane effects. It can be shown that such a procedure allows to extract mesostructurally motivated average localisation orientations for various coupled flexural-membrane loading paths [5].

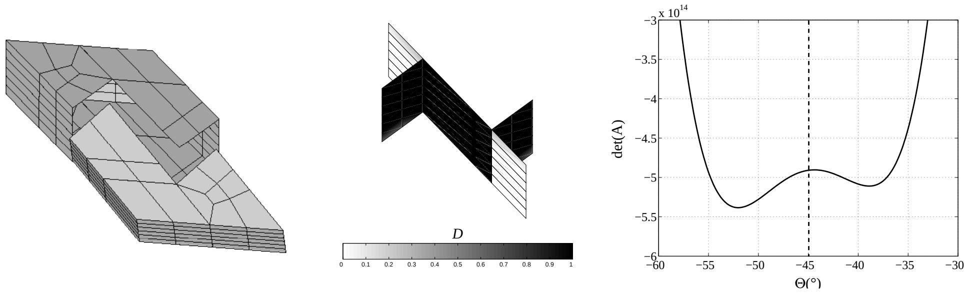

Figure 1: Out-of-plane stair-case bending failure at 45° (brick shape factor of 0.5): Deformed shape of the unit cell (left), joint damage (centre) and related acoustic tensor determinant spectrum (right).

When structural scale localisation is detected, a strong discontinuity approach for shells is used, as proposed in [6], where only the Kirchhoff-Love discontinuity modes are activated (in-plane displacements and rotations). The kinematics of the description is generalised by considering an element-based displacement jump added to the regular part of the displacement field. To determine the additional displacement jump field, the weak form of equilibrium is solved together with a continuity condition on generalised stresses (normal efforts and moments) along the discontinuity line. In contrast with the discontinuity closed-form evolution laws used in [6], this coarse scale description is here coupled with the computational homogenisation concepts to set up a nested computational procedure for flexural effects. Prior to localisation, the generalised stresses and the generalised tangent stiffness are obtained numerically from a unit cell computation based on the extended scale transition rules. Upon localisation, the bulk material is assumed to unload elastically along the secant stiffness. The behaviour of the discontinuity is further deduced from the scale transition on a damaging unit cell, based on an energy equivalence which takes into account the finite size of the fine scale volume on which damage localisation occurs. The results obtained with this framework will be illustrated to show that mesostructurally motivated preferential damage orientations can be naturally incorporated into structural computations.

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