Damage induced anisotropy in masonry walls

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Introduction

Masonry is a composite material exhibiting a complex non-linear behaviour due to possible cracking in each of its phases. The complexity resides in the interplay of the initial orthotropy of the material and cracking induced anisotropy. Failure modes are strongly dependent on the principal stresses and their orientation with respect to the initial material directions [1].
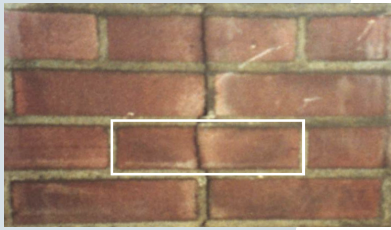

Figure 1 *Vertical cracking in masonry sample*

Most existing macroscopic masonry descriptions are phenomenological and based on weakly motivated assumptions, not accounting for realistic macroscopic effects of constituents failure.

Using the periodic structure of masonry and simplifying assumptions, the objectives are to assess:

- ☐ whether simple mesoscopic damage laws are able to reproduce in-plane failure
- ☐ under which conditions macroscopic full anisotropic cracking induced effects are present

Unit cell computations

Homogeneous macroscopic fields are prescribed on a unit cell by enforcing the displacement fields to be strain-periodic [2] (colors indicate tied sides). The load is applied using stress-control imposed through the six corner nodes.

Figure 2 *Tyings on running bond unit cell*

The cell is loaded with proportional stress paths. The constituents are modeled under the plane stress assumption using a nonlocal scalar damage mechanics setting with different sensitivities to compressive and tensile stress states. No nonlocal interactions are included between neighboring points of different phases. The evolution of the macroscopic material symmetry may be illustrated by homogenization of damaged configurations.

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Results

Figure 3 presents a damaged cell subjected to combined vertical compression and shear, a stress state usually encountered in masonry structures. Damage develops in the mortar joints, leading to a fully anisotropic secant stiffness as illustrated by the corresponding homogenized stiffness matrix. The cracking induced macroscopic anisotropy evolution is strongly connected to the geometric arrangement of the material. Its coupling with initial orthotropy is too complex to be represented using phenomenological continuum mechanics description.
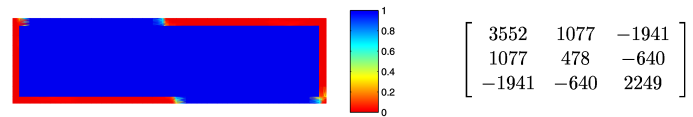

$$
\begin{bmatrix}
3552 & 1077 & -1941 \\
1077 & 478 & -640 \\
-1941 & -640 & 2249
\end{bmatrix}
$$

Figure 3 *Non orthotropic damaged cell configuration*

The related failure envelope for moderate stress states (figure 4) illustrates the variability of the failure mechanisms according to the stress path.
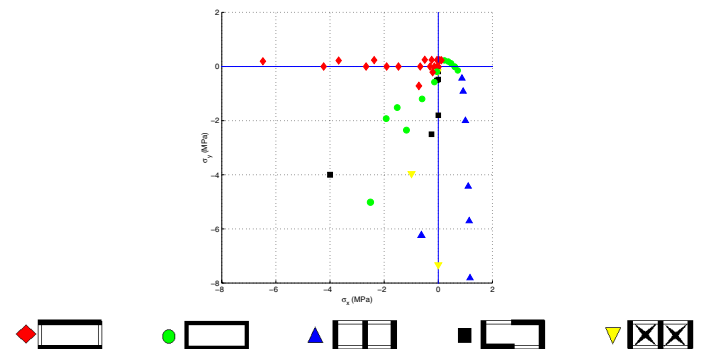

Figure 4 *Failure points in stress space with failure modes*

Conclusions and perspectives

Results show that full anisotropy should appear in macroscopic models, preferably postulating damage evolution at the mesoscale in multi-scale representations. It also suggest that essentials of the macroscopic behaviour may be captured assuming constant damage in given sub-regions of a unit cell. Developments are required to include 3D effects for the simulation of compressive failure.

References:

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