A computational multiscale approach to couple hygro-mechanical responses of large-scale masonry walls

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ABSTRACT

We present a computational multiscale approach able to solve, both efficiently and accurately, the nonlinear problems of humidity diffusion and mechanical damage of large-scale masonry walls, and their coupling in terms of the effects of the humidity diffusion on the mechanical response and the effects of the mechanical degradation on the diffusion process.

The models of the two nonlinear problems consider the wall as a lattice-like discrete system [1, 2]. The field variables are associated in an integral (average) sense to each block composing the wall, i.e. sandstone units, while the nonlinear response is assumed to be concentrated at interface elements, i.e. cement mortar joints linking blocks. Although such models drastically simplify the corresponding physical phenomena, or more sophisticated models [3], they present all the relevant nonlinearities of the problems, such as the water uptake process under evaporation conditions, and the structural frictional toughness along with the softening material response: such nonlinearities often lead to failure in convergence within standard numerical simulators, and computational costs highly increase as wall dimensions are larger and larger [1].

Following the approach proposed in [4] for pure mechanical contexts, the discrete systems are solved by an iterative multilevel strategy mimicking algebraic multigrid methods, where local solutions, those of balancing between two linked blocks, and global solutions, those of balancing two contiguous patterns of blocks, work as nested sequences able to correct error oscillations, high and low respectively.

We conduct a numerical testing, whose meaningful results are reported in the present work, showing in particular how the diffusion properties are affected by existing damage patterns in equilibrium with certain loading conditions, and conversely, how strength and elastic properties are degraded by existing distributions of humidity through equilibrated water uptake processes.

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