A multilevel domain decomposition method based on a couple-stress homogenization approach for the failure analysis of masonry structures

***Lorenzo Leonetti[1], †Fabrizio Greco[1], Patrizia Trovalusci[2], and Raimondo Luciano[3]**

[1]Department of Civil Engineering, University of Calabria, Rende, Italy
[2]Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Rome, Italy
[3]Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, Italy

*Presenting author: lorenzo.leonetti@unical.it
†Corresponding author: lorenzo.leonetti@unical.it

Abstract

Multilevel domain decomposition approaches have been shown to be successful in efficiently studying the nonlinear response of heterogeneous structures, especially when the principle of scale separation ceases to be valid due to the occurrence of strain localization phenomena [1–4]. These approaches have been recently applied to the damage analysis of masonry structures, usually in the framework of first-order (i.e. Cauchy) macro-continuum models [5].

In this work, a refined approach for the multiscale failure analysis of masonry structures is presented, which adopts a couple-stress homogenization approach to derive the overall elastic moduli for the undamaged masonry [6]. Couple-stress continuum model can be regarded as a constrained version of micropolar continua [7–9], for which the role of relative macro-/micro-rotations is neglected. Damage is taken into account at a conventionally defined microscopic scale, at which mortar joints are explicitly modeled as zero-thickness cohesive interface elements embedded in a finite element mesh representing the adjacent units.

Furthermore, an adaptive model refinement strategy is provided to increase the computational efficiency of the proposed multilevel domain decomposition method. Such a strategy requires the definition of a zoom-in criterion able to replace the homogenized macro-elements with the corresponding microstructures. To this end, a microscopically informed first failure surface is derived, relying on the detection of incipient damage nucleation at mortar joints.

The proposed multilevel strategy is validated via different numerical experiments devoted to the nonlinear analysis of masonry panels subjected to various loading conditions. Finally, suitable comparisons with experimental results and other numerical approaches are presented.

Keywords: **Couple-stress continua, multiscale domain decomposition method, masonry structures, nonlinear analysis, cohesive fracture**

Acknowledgments. This work is supported by Italian Ministry of University and Research (P.R.I.N. National Grant 2015, B86J16002300001; Sapienza and Calabria Research Units) and by Sapienza University Grant 2016, B82F16005920005.

References

[1] Ghosh, S., Lee, K. and Raghavan, P. (2001) A multi-level computational model for multi-scale damage analysis in composite and porous materials, *International Journal of Solids and Structures* **38**(14), 2335–2385.

[2] Lloberas-Valls, O., Rixen, D.J., Simone, A. and Sluys, L.J. (2012) Multiscale domain decomposition analysis of quasi-brittle heterogeneous materials, *International Journal for Numerical Methods in Engineering* **89**(11), 1337–1366.

[3] Greco, F., Leonetti, L. and Lonetti, P. (2013) A two-scale failure analysis of composite materials in presence of fiber/matrix crack initiation and propagation, *Composite Structures* **95**, 582–597.
[4] Greco, F., Leonetti, L., Nevone Blasi, P. (2014) Adaptive multiscale modeling of fiber-reinforced composite materials subjected to transverse microcracking, *Composite Structures* **113**(1), 249–263.
[5] Greco, F., Leonetti, L., Luciano, R. and Nevone Blasi, P. (2016) An adaptive multiscale strategy for the damage analysis of masonry modeled as a composite material, *Composite Structures* **153**, 972–988.
[6] Leonetti, L., Greco, F., Trovalusci, P., Luciano, R. and Masiani, R. (2018) A multiscale damage analysis of periodic composites using a couple-stress/Cauchy multidomain model: Application to masonry structures, *Composites Part B: Engineering* **141**, 50–59.
[7] Masiani, R. and Trovalusci, P. (1996) Cosserat and Cauchy materials as continuum models of brick masonry, *Meccanica* **31**, 421–432.
[8] Pau, A. and Trovalusci, P. (2012) Block masonry as equivalent micropolar continua: the role of relative rotations, *Acta Mechanica* **223**(7), 1455–1471.
[9] Trovalusci, P. and Pau, A. (2014) Derivation of microstructured continua from lattice systems via principle of virtual works: the case of masonry-like materials as micropolar, second gradient and classical continua, *Acta Mechanica* **225**(1), 157–177.