Nonlinear Computational Homogenization Experiments

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Abstract

Introduction
Numerical homogenization is based on the usage of finite elements for the description of average properties of materials with heterogeneous microstructure and composites. Original development of the method for linear problems can be extended to cover nonlinear behaviour. The steps of the method and representative examples related to masonry structures are presented in this paper.

Use of COMSOL Multiphysics®
The Representative Volume Element (RVE) finite element model of the masonry is created and solved within COMSOL Multiphysics®. It consists of the bricks and the mortar joints, thus the material which connects the bricks. Linear displacement boundary conditions are applied as loading in the boundaries, while a non-linear constitutive law is chosen for the mortar joints. Parametric analysis has also been chosen, and a parameter is incorporated for the description of the loading. With this way, several RVE models with gradually increasing loading, are solved. Results concerning the average stress and strain in the RVE domain are then calculated, by using the subdomain integration postprocessing capability of COMSOL Multiphysics®.

By using the script file of the model, the average stress and strain vectors are obtained for each parameter. In addition, for each loading path and each loading level, three test incremental loadings are applied to the RVE. Consequently, tangent stiffness information is obtained for the particular loading path and loading level, by incrementally solving the Hooke's law ds=C_t de, for the unknown tangential stiffness C_t. Finally, a data base of the tangent stiffness and the stress is created, or a neural network is used, for an overall nonlinear homogenization procedure of a masonry macroscopic structure, in a FEM2 approach. Results are compared with a direct heterogeneous macro model. One representative volume element of a masonry structure is shown in Figure 1. Bricks are linearly elastic and mortar is elastoplastic.

Results
The nonlinear homogenized average stress-average strain laws from each loading path and each loading level of the RVE are obtained. Next, the behaviour of a macroscopic structure is analyzed, by using the information given by the microscopic analysis. Structural characteristics obtained by the overall scheme, are examined.

Conclusion
In this work a method for simulating heterogeneous structures is presented (here masonry). Nonlinear analysis and numerical homogenization are applied, in the microscopic representative sample of the material. The average material properties are then used in a second step, for the simulation of the overall macroscopic heterogeneous structure.

Reference

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Figures used in the abstract

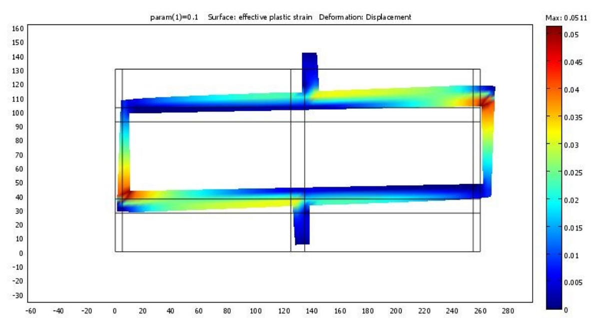

Figure 1: Representative volume element of masonry and effective plastic strain of elastoplastic mortar.