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NONLINEAR HOMOGENIZATION IN MASONRY STRUCTURES

Georgios A. Drosopoulos[1,2], Maria E. Stavroulaki[2], Georgios E. Stavroulakis[2] and Peter Wriggers[1]

[1] Leibniz University of Hannover, D-30167 Hannover, Germany, wriggers@ikm.uni-hannover.de, drosopoulos@ikm.uni-hannover.de ; www.ikm.uni-hannover.de
[2] Technical Universtity of Crete, GR-73100 Chania, Greece, gdrosopoulos@isc.tuc.gr; gestavroulakis@isc.tuc.gr; p.leonidas@yahoo.gr; www.comeco.tuc.gr

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Numerical homogenization is based on the usage of finite element analysis for the description of average properties of materials with heterogeneous microstructure [1]. Computational homogenization [2] is a method of considering the non-linear behaviour of a microscopic material, by simulating in each macro Gauss point and time step, the corresponding micro model. This microscopic model includes every heterogeneity and non-linearity. In addition, the macroscopic stress-strain law is obtained only numerically. Among other non-linear laws, elastoplastic material laws as well as unilateral contact interfaces can be used in the microscopic scale [3-5].

The practical steps of the proposed approach and representative examples related to masonry structures are presented in this paper. The non-linear Representative Volume Element (RVE) of a masonry structure, including parts with elastoplastic material behaviour (e.g. mortar) or unilateral contact interfaces and cracks, is created and solved. Parametric analysis has been chosen and used for the description of the strain loading. Thus, several RVE models with gradually increasing loading are solved. Results concerning the average stress and strain in the RVE domain are then calculated. In addition, the stiffness is estimated for each loading path and loading level. Finally, two databases for the stiffness and the stress are created, a metamodel based on MATLAB interpolation is used, and an overall non-linear homogenization procedure of the structure, in a FE^2 approach, is considered. Results are compared with direct heterogeneous macroscopic models.

The key idea of the present work is to replace the microscopic simulation of the RVE, which is considered within each time step of the computational homogenization method, with two databases containing information related to the stress and the stiffness of the macro model. This information is transferred back to the macroscopic structure. Thus, instead of solving the RVE in each Gauss point and time step, which is a time consuming procedure, an interpolation of the proper quantity from the databases is considered. This concept has the following steps:

Step 1. Creation of a composite RVE with COMSOL Multiphysics. It consists of a matrix and a number of fibers, or of two materials separated by a crack. A unilateral contact law has been applied to simulate the interfaces between the constitutive materials or the crack. A classical plasticity law has been also applied, to depict the failure of mortar element.

Step 2. A number of loading paths are developed and applied to the RVE. To do this, plane stress parametric analysis is used. Each loading path consists of a number of increments. Linear displacement or periodic boundary conditions are applied as loading to the boundaries of the RVE.

Step 3. After analysis of each RVE is completed, the average stress is calculated, within

COMSOL. Steps b) and c) are repeated for each loading path and each loading level, but now three test incremental loadings are applied to the RVE. Then, by incrementally solving the Hooke's law, stiffness information is obtained for the particular loading path and level. This will be the tangent stiffness in the macro level, of the overall homogenization scheme.

Step 4. Two databases have been finally created: one that corresponds strains to stresses and another that corresponds strains to stiffness information. These are incorporated in an overall FE^2 computational homogenization scheme developed with MATLAB, for the simulation of macroscopic composite structures.

Step 5. Comparison of the results with direct heterogeneous macroscopic models created in other commercial software packages is used to evaluate the whole procedure.

According to the results, a satisfactory comparison between the proposed approach and the direct heterogeneous macro models arises. Furthermore, the non-linear behaviour of the heterogeneous, masonry structure can be successfully depicted by the proposed model, within the accuracy of the utilized models.

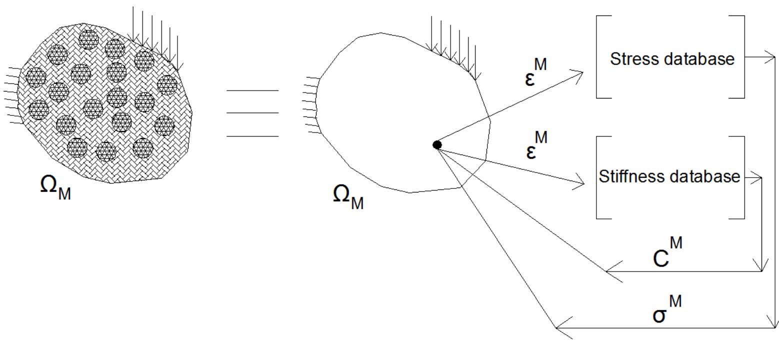

Figure: The proposed multiscale homogenization scheme.

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