Multiscale reduced order model for the analysis of damaging masonry domes and vaults

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The historical and architectural heritage of many European countries is composed of masonry structures, which suffered damaging processes due to their old building period and the peculiar mechanical properties of the material. Therefore, developing efficient numerical tools to evaluate their structural performance, especially under seismic loads, is a challenging task for the scientific community. Among the available methodologies [1], multiscale models, developed within suitable finite element codes, represent an effective procedure to describe onset and evolution of microcracks and follow the damage paths up to failure.

In this work, the multiscale formulation proposed in [2] is adopted to investigate response of masonry structures with periodic texture. Different structural models are assumed at the two scales of analysis, thus exploiting the advantages of each formulation. The constitutive response of the homogeneous Mindlin-Reissner shell considered a the macroscale is derived from the analysis of a representative three-dimensional masonry unit cell (UC). This contains all the geometric/constitutive information on the microstructure, being composed by elastic bricks bonded by potential damage/slip surfaces, modeled with interfaces elements. The homogenization process linking the two scales is based on the Transformation Field Analysis [3]. This procedure relies on the subdivision of the nonlinear regions of the UC, i.e. the interfaces representing mortar joints, in subdomains where prescribed variation of the inelastic quantities is assumed. The effect of macroscopic strains in the UC and that of the nonlinear quantities occurring in each subdomain is preliminary determined by performing a set of linear elastic analyses, which allow to determine proper operators to be used to solve the evolutive nonlinear problem of the UC within the multiscale simulation. Hence, the link of the two scales is obtained through a reduced order model that avoids the micromechanical modeling of the UC during the analysis, with indubitable computational advantages.

The model is implemented in a finite element code that uses a shear locking free thick shell formulation at the macroscale [4]. This is suitable for the analysis of both flat and curved masonry elements. Hence, the attention is here focalized on arches, domes and vaults, as these are structural elements largely adopted in monumental and urban buildings. Their overall behavior is studied in terms of load-displacement global curves and failure mechanisms. Damaging paths are in depth analyzed in view of a proper design of structural reinforcements aimed at improving the structural performance. The reliability of the results is proved by comparison with experimental data or solutions derived from detailed micromechanical simulations.

References

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