Multiscale couple-stress model, FEM/DEM approach and Limit Analysis for the in-plane failure analysis of masonry walls: a critical review

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Abstract

Despite its complexity, the accurate structural modelling of masonry still represents an active field of research, due to several practical applications in civil engineering, with special reference to the preservation and restoration of cultural heritage items. The above-mentioned tasks call for very accurate analyses of masonry structures, able to capture their peculiar mechanical features in the nonlinear range. With this purpose three different approaches are compared to predict the in-plane failure behaviour of masonry walls: a FEM-based multiscale Couple-Stress model, a combined Finite-Discrete Element Model (FEM/DEM) and non-standard Limit Analysis performed by means of a code specifically developed for masonry (ALMA).

On one hand, the FEM-based Couple-Stress multiscale model may be regarded as an enhanced version of the multi-level domain decomposition approach, recently applied to masonry [1]. Both the micro-constituents (i.e. units and joints) are modelled in a standard Cauchy continuum setting, while the homogenized masonry material employed at the macro-scale is represented as a Couple-Stress continuum, i.e. a constrained version of the Cosserat model, which is able to take into account the size effects related to the bending deformations [2]. A suitable macro-to-micro switching criterion is introduced, in order to adaptively zoom-in the regions affected by damage initiation, thus reducing the overall computational costs.

On the other hand, the FEM/DEM method, initially developed for the study of granular materials, has been recently adopted for the study of masonry material [3][4]. FEM/DEM is based on a micro-modelling approach. Here blocks are modelled as rigid bodies and mortar joints are modelled as zero thickness elasto-plastic Mohr-Coulomb interfaces. The method is a combination of classic FE and DE models. The model relies on a triangular discretization of the domain with embedded crack elements, that activate whenever the peak strength is reached. FEs allows to reproduce elastic strain while DEs are able to model the frictional cohesive behavior exhibited by masonry.

Finally, Limit Analysis is able to provide fast and reliable results in term of collapse multiplier and relative cinematism. Here a non-standard Limit Analysis (non-associative rules) is adopted [5][6][7] via an own made procedure based on Non-Linear and Non-Convex Mathematical Programming, taking into account friction at interfaces, settlements of the supports, reinforcements and/or cohesion among stones. A numerical comparison is proposed to evaluate the field and limit of application of the three approaches.

Keywords: **Multiscale, Couple-Stress, FEM/DEM, Limit Analysis, Masonry**.

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