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A COSSERAT FINITE ELEMENT WITH DAMAGE AND PLASTICITY FOR THE IN-PLANE RESPONSE OF MASONRY STRUCTURES

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ABSTRACT

The development of efficient and accurate numerical methods for the analysis of the structural response of masonry is a significant challenge, with reference both to the preservation of ancient constructions and to the rational design of new buildings.
Various approaches have been proposed in literature to reproduce masonry structural behaviour at different levels: micro-structural models discretize bricks and mortar separately by adopting suitable constitutive laws for each component; on the other hands, macro-models describe masonry as an equivalent homogenous continuum and require the formulation of phenomenological constitutive relationships. Obviously, the first approach results, at the same time, very accurate and computationally very burdensome, so to be useful only for the analysis of small details of structures. Nevertheless, micro-models may profitably be employed to calibrate the mechanical parameters of the phenomenological constitutive models and the evolution laws of the inner variables. A wide literature has been devoted to develop homogenization techniques with the aim of identifying constitutive models available for macro-structural analyses on the basis of micro-structural models.
Unfortunately homogenization procedures are well established only in the context of linear constitutive behaviour. In particular, Masiani et al. [1] have observed that, in order to take into account information related to the actual heterogeneous and discontinuous nature of masonry, an orthotropic Cosserat continuum has to be adopted at the macro-level, which is capable to discern the impact of the micro-structure texture at the macro-scale. As for the non-linear constitutive behaviour, only computational approaches can at present be adopted for the homogenization.
In recent years a few numbers of numerical models for masonry have been proposed. Lourenco [2] has formulated a plasticity model for in-plane loaded walls, which well reproduces some experimental results. Papa [3] has proposed an orthotropic unilateral damage model for masonry based on a numerical homogenization to keep into account the texture of bricks and mortar. Berto et al. [4] have developed an orthotropic damage model for the analysis of brittle masonry subjected to in-plane loading based on the

definition of four independent damage parameters, taking into account the stiffness recovery at crack closure.

The aim of this paper is to formulate a Cosserat finite element for the analysis of 2D masonry structural problems subjected to in-plane loads, both for the monotonic and cyclic case. A phenomenological damage - plastic model is formulated, where damage scalar variables which describe the degrading paths of the material are introduced, and the generalized von Mises plasticity model for Cosserat continuum is adopted.

It is an isotropic model based on the definition of two damage scalar variables, which describe different degrading processes in tension and compression, controlled by means of two distinct damage limit functions. The adoption of the Cosserat model rests on two main reasons: the first is related to the possibility of properly modelling the effects of the micro-structure on the global response, the second resides on the possibility to exploit its natural regularization capability in presence of strain-softening constitutive behaviour.

With regard to the computational aspects, a predictor-corrector procedure is adopted to solve the evolution problems of the damage variables and a displacement-based finite element is formulated and implemented in the numerical code FEAP [5].

In the final part of the paper some numerical applications on simple masonry panels are presented.

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