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A 2D COSSERAT MODEL BASED ON A MULTI-SCALE TECHNIQUE FOR THE STRUCTURAL RESPONSE OF BRICK MASONRY

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ABSTRACT

The rational design of efficient repairing techniques for the preservation of historical masonry buildings requires an accurate analysis of the masonry complex damaging mechanisms under external loads, which strongly influence the global structural response. Nowadays numerical procedures offer the most powerful tool to perform reliable structural analyses, allowing to take into account the complex nonlinear behaviour of the masonry different constituents. In fact, masonry is a heterogeneous material with periodic microstructure; furthermore, each of its constituents, bricks and mortar, exhibit a brittle like mechanical behaviour due to the damaging process.
In literature a wide variety of models have been proposed to reproduce masonry structural responses under external loadings. The different accuracy obtained in the description of the global load-displacement response curves and of the local stresses and damage distributions is related to the level of the modelling process.
Micro-structural approaches adopt a very fine discretization, where bricks and mortar are modelled separately by using damage constitutive laws, properly formulated for each of them. Such numerical models may produce very detailed and accurate results, but are computationally very burdensome [1, 2]. In order to limit computational costs, macro-models have been usually employed in structural calculations; they describe masonry as an equivalent homogenous continuum and make use of phenomenological constitutive relationships [3, 4]. The mixing theory [5] is another common technique applied to model the behaviour of a composite material as an equivalent homogeneous medium, where each component contributes to the overall response proportionally to its volume portion.
A wide literature has been devoted to develop homogenization techniques with the aim of determining constitutive models available for macro-structural analyses on the basis of micro-structural models. In particular, homogenization procedures are well established in the context of linear elastic material behaviour allowing to identify masonry macroscopic elastic properties [6]. In the field of non-linear constitutive

behaviour, various computational approaches may at present be adopted for the homogenization, mainly based on multi-scale techniques [7, 8]. It has to be noted that, in order to take into account information related to the actual heterogeneous and discontinuous nature of masonry, an orthotropic Cosserat continuum may be needed at the macro-level, which is capable to discern the impact of the micro-structure texture at the macro-scale, both in the linear elastic and in the nonlinear range [9].

In this paper a multi-scale procedure is presented where the heterogeneous masonry material is modelled at the micro-level as a classical Cauchy medium, and at the macro-level as a homogeneous equivalent Cosserat medium. Plane-stress and small displacement assumptions hold. The displacement field on a unit cell is expressed as a polynomial expansion and a periodic perturbation. The minimum order of the polynomial displacement field and its coefficients are dictated by the macroscopic generalized strain measures defined for the Cosserat continuum. Different nonlinear constitutive laws with damage are adopted for the masonry constituents present in the unit cell. Literature findings suggest that at the micro-scale it is possible to use scalar damage models for the individual phases. An integral procedure based on the Hill-Mandel equivalence is used to evaluate the generalized stress measures on the unit cell.

Some numerical applications on simple masonry panels subjected to in-plane loadings are presented; they show that realistic in-plane damage patterns and global load-displacement curves, as typically found in experimental tests, are obtained.

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