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A COMPUTATIONAL HOMOGENIZATION TECHNIQUE COUPLED WITH A YIELDING CRITERIA FOR THE STRUCTURAL RESPONSE OF MASONRY PANELS

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ABSTRACT

The proper maintenance and the restoration of the historical masonry buildings are important tasks in civil engineering. A deep knowledge of the complex damage mechanisms taking place at the level of the components (bricks and mortar) of such a composite material is required to realistically reproduce the overall behavior of the structure.

Many efforts have been devoted to capture the global response of the composite structures by means of the appropriate constitutive laws. Nevertheless, due to the interaction between components, the behavior of the masonry is intrinsically complex and thus cannot be well-reproduced by methods utilizing the phenomenological material laws at the macro-scale.

Several approaches have been carried out to overcome these difficulties. For example the *mixing theory* [1] is a common technique used to reproduce the behavior of the composite material, considered as a homogeneous equivalent continuum, where each component contributes to the overall response, proportionally to its respective volumetric fraction.

In the *homogenization theory* the mechanical behavior of the composite is simulated using two scales: the macro-scale, in which the material is considered to be homogeneous and the micro-scale where the microstructure is represented in detail. Every point of homogenized material on the macro-scale is associated to the *representative volume element*, which is the portion of the composite material that is able to describe the realistic material response. This technique allows to identify the properties of the homogenized global continuum medium via the constitutive behavior of the underlying heterogeneous structure. Great amount of literature is dedicated to the development of homogenization techniques dealing with linear [2, 4] and non–linear [3, 5] constitutive behavior of the components.

In this work, the behavior of masonry panels is studied using a first order homogenization technique. Masonry is considered to be a periodic material characterized by the series of equal representative volume elements. The problem on the micro-scale is *strain driven* in the following sense: the microstructure receives a homogenized strain tensor and calculates the corresponding homogenized stresses.
In the formulation proposed in this work, each component is described by its individual constitutive law. Specifically, masonry employs two different isotropic damage constitutive models for the bricks and the mortar, respectively. A regularization technique based on the fracture energy [6] is used to treat the localization problems developed in the quasi-brittle materials.
The two-scale problem is solved using different finite element programs which communicate through the homogenized variables. An iterative Newton–Raphson scheme based on the displacement method, which considers the interaction between scales is developed. From the point of view of the numerical implementation, the problem is managed by means of a *parallelized master–slave* approach, where the global scale is the master and the local scale models (corresponding to each integration point of the global discretization) are the slaves.
The computational costs are usually high in terms of calculation times and memory storage, mainly in the non–linear range.
Therefore the current formulation is improved with a new technique based on the evaluation of a yield function before solving the problem at the local scale. The yield function is obtained in a manner that is consistent with the topology of the micro–structure.
The message–passing to the micro–scale is allowed only when the elastic threshold is excited at a macroscopic point, otherwise all the calculations remain at the global level. Finally, numerical examples are included to show the capabilities of the proposed formulation and the memory saving benefits, compared with standard homogenization techniques, are highlighted.

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