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Editorial

New Trends in the Numerical Analysis of Masonry Structures

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The Special Issue of The Open Civil Engineering Journal entitled "New trends in the numerical analysis of masonry structures" provides an insight into the most up-to-date numerical techniques used at academic and professional level to perform advanced structural analyses on masonry structures.

Masonry is a building material that has been used for more than ten thousand years. In many countries, masonry structures still amount to 30–50% of the new housing developments. Also, most structures built before the 19th century and still surviving are built with masonry. Masonry is usually described as a heterogeneous material formed by units and joints, with or without mortar, and different bond arrangements. Units are such as bricks, blocks, ashlars, adobes, irregular stones and others. Mortar can be clay, bitumen, chalk, lime/cement based mortar, glue or other. The almost infinite possible combinations generated by the geometry, nature and arrangement of units as well as the characteristics of mortars raise doubts about the accuracy of the term "masonry". Still, much information can be gained from the study of regular masonry structures, in which a periodic repetition of the microstructure occurs due to a constant arrangement of the units (or constant bond).

The difficulties in performing advanced testing and providing sufficiently general numerical models for this kind of structures are basically due to the innumerable variations of masonry typologies, the large scatter of in situ material properties and the impossibility of reproducing all in a specimen. Therefore, most of the advanced numerical research carried out in the last decades concentrated in brick / block masonry and its relevance for design. Accurate modelling requires a comprehensive experimental description of the material, which seems mostly available at the present state of knowledge.

From a numerical point of view, masonry behaviour is quite complex to model, exhibiting non-linearity very early during the loading process, with softening in both tension and compression, low ductility and differed deformations under sustained loads. In addition, masonry is the result of the assemblage of bricks or stones, where mortar is laid, with common geometric irregularities adding further complexity to the problem.

The special issue collects nine papers from experts in the field, including contributions of researchers from six different countries (Czech Republic, Iran, Italy, Portugal, Spain, Switzerland), either devoted to the utilization of non-standard numerical models for case-studies or presenting new approaches for the interpretation of masonry behaviour in presence of different kinds of non-linearity. The effort is always to put the knowledge beyond the existing state-of-the art.

Karbassi and Lestuzzi [1] present a fragility analysis performed on unreinforced masonry buildings, conducted by means of the so called Applied Element Method (AEM), to define fragility curves of typical masonry buildings which may be regarded as representative of building classes. A series of nonlinear dynamic analyses using AEM are performed for a 6-storey stone masonry and a 4-storey brick masonry building using more than 50 ground motion records. The distribution of the structural responses and inter-storey drifts are finally used to develop spectral-based fragility curves for the five European Macro-seismic Scale damage grades.

In the second paper, Milani *et al*. [2] perform a detailed non-linear analysis (both pushover and limit analysis) on the San Pietro di Coppito bell tower in L'Aquila, Italy, trying to have an insight into the causes of the collapse occurred during the devastating 2009 earthquake.

Sykora *et al*. [2] review several topics related to the homogenization of transport processes occurring in historical masonry structures. Particular attention is paid to variations of temperature and moisture fields, whose contribution to structural damage usually far exceeds the effects of mechanical loadings. The concept of Statistically Equivalent Periodic Unit Cell (SEPUC) is reviewed and utilized to deal with historic masonry and random patterns. Accepting SEPUC as a reliable representative volume element, a Fast Fourier Transform to both the SEPUC and large binary samples of real masonry is used to tackle effective thermal conductivities problems. Fully coupled non-stationary heat and moisture transport problems are addressed next in the framework of a two-scale first-order homogenization, with emphases on the application of boundary and initial conditions at the meso-scale.

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A structural case study is presented by Araujo *et al*. [3]. The authors propose a numerical seismic assessment of the St James Church in Christchurch, New Zealand, affected by the recent 2011 earthquake and subsequent aftershocks. The structural behaviour of the church is evaluated using the Finite Element modelling technique, in which the nonlinear behaviour of masonry is taken into account by proper constitutive assumptions. Two numerical models are critically compared, one incorporating the existing structural damage and the other considering the intact structure.

A different case study is then proposed by Milani *et al*. in [4]. The authors focus on the seismic behaviour of the Maniace Castle in Siracusa, Italy, utilizing accurate 3D Finite Element discretizations. The behaviour of the structure under horizontal loads is analysed in detail by means of different approaches and a comparison with a model representing the castle in its original configuration is provided.

Roca *et al*. [6] present a continuum model for the simulation of the viscous effects and the long-term damage accumulation in masonry structures. The rheological model is based on a generalized Maxwell chain representation, with a constitutive law utilizing a limited number of internal variables. The FE simulation of the construction process of the representative bay of Mallorca Cathedral is finally discussed, together with the analysis of the long-term effects.

Akhaveissy [7] presents a non-linear finite element method to predict the behavior of unreinforced masonry structures in-plane loaded. The disturbed state concept (DSC) with modified hierarchical single yield surface (HISS) plasticity is used to characterize the constitutive behavior of masonry in both compression and tension. The DSC model allows for the characterization of non-associative behavior through the use of disturbance. It computes micro-cracking during deformation, which eventually leads to fracture and failure. The model is verified on laboratory specimens and real scale panels.

Acito and Milani [8] use a FE homogenization approach for the interpretation of existing crack patterns induced by foundation settlement on old masonry buildings. The approach is general and may be applied to any case study exhibiting differential foundation settlement. For a direct mechanical interpretation of the reasons at the base of the formation of the crack pattern, a simple but effective fully equilibrated model is also discussed, able to predict quite accurately the position of the cracks. The model is also utilized to estimate soil elastic vertical stiffness –within a Winkler approximation- to be used in a second phase with the fully non-linear FE code.

Finally Reccia *et al*. in [9] investigate the possibilities of the Discrete Element Method (DEM) applied to the kinematic limit analysis of out-of-plane loaded masonry walls. Blocks are discretized with triangular rigid FEs and are regarded as rigid bodies connected by zero thickness Mohr-Coulomb-type interfaces. The applied method is known as combined FEM/DEM.

In conclusion, I wish to thank all the authors for their valuable contributions. All manuscripts underwent technical peer review. I therefore also wish to thank all the reviewers for their critical comments which undoubtedly improved the original technical value of all contributions.

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