Out-of-plane behaviour of URM walls subjected to two-way bending by means of Discrete Macro-Element (DME) numerical simulations

César Chácara*, Francesco Cannizzaro[†], Bartolomeo Pantò[†], Davide Rapicavoli[†], Ivo Caliò[†], and Paulo B. Lourenço^{††}

> * Department of Engineering, Civil Engineering Division Pontificia Universidad Católica del Perú PUCP San Miguel, Lima, Perú e-mail: c.chacara@pucp.pe, web page: http:// www.pucp.edu.pe

[†] Department of Civil Engineering and Architecture University of Catania 95125 Catania, Italy email: francesco.cannizzaro@dica.unict.it, bpanto@dica.unict.it, daviderapicavoli@hotmail.it, ivo.calio@unict.it - web page: https://www.unict.it

> ^{††} ISISE, Department of Civil Engineering University of Minho
> 4800-058 Azurém, Guimarães, Portugal
> email: pbl@civil.uminho.pt - web page: https://www.uminho.pt

ABSTRACT

The global response of structures which are not governed by a box-type behaviour is given by a complex interaction between in-plane and out-of-plane behaviours of masonry panels. It has been observed, from previous earthquakes, that the out-of-plane failure mechanisms can represent the main cause of structural collapse of historical masonry structures subjected to seismic events. Numerous experimental and analytical studies associated with the out-of-plane response of structures mostly considered the effects of one-way bending in which the constituent elements can be simulated as rigid blocks. With this regard, recent experimental campaigns and numerical simulations have been conducted in order to investigate the out-of-plane behaviour of masonry walls subjected to two-way bending. These investigations have demonstrated the complexity of this mechanism and, thus, the needed of accurate numerical tools able to allow reliable predictions both in terms of ultimate strength and failure mechanisms.

In this paper, the out-of-plane behaviour of unreinforced masonry walls, subjected to shaking table tests, is investigated by means of a simplified and original computational strategy denoted as Discrete Macro-Element Method DMEM, proposed by the authors in previous researches. This computational tool is capable of simulating the main in-plane and out-of-plane mechanisms of unreinforced masonry structures with a very low computational burden if compared to nonlinear FEM simulations. A comparison between experimental and numerical results is conducted in order to validate the proposed modelling approach. Subsequently, parametric analyses are conducted in order to determine the main mechanical and geometrical characteristics influencing the 2-way out-of-plane bending response of masonry walls.