A force-based macroelement with damage and plasticity for the analysis of masonry structures

†*Marialuigia Sangirardi[1], Daniela Addessi[1], and Domenico Liberatore[1]

[1]Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Rome, Italy

*Presenting and †Corresponding author: marialuigia.sangirardi@uniroma1.it

Abstract

The behaviour of masonry structures is strongly nonlinear, even at small stress/strain level. Moreover, when subjected to seismic actions, they exhibit a complex response, characterized by hysteresis together with stiffness and/or strength degradation and, in some cases, also pinching. All these mechanisms need to be accurately described and included in numerical models, especially when cyclic excursions in the inelastic range are expected.

Different approaches are widely studied and can be adopted to do this, relying on microscopic, macroscopic, multi-scale and macroelement formulations. The latter has proven to be an efficient tool for the structural analysis of masonry buildings because it represents a fair compromise in terms of accuracy and computational cost [1,2]. In the field of macromodelling, this work is intended to present a macroelement able to reproduce the cyclic response of masonry panels under in plane horizontal loads. It accounts for the typical flexural and shear in-plane failure mechanisms via two flexural hinges and a shear link, arranged in series with a central elastic beam element.

The hysteretic behaviour is reproduced with a modified version of the well-known Bouc-Wen model [3]. The constitutive law of the flexural hinges and of the shear link is formulated considering both strength and stiffness deterioration by means of a single damage variable *D*, which has been included in the smooth hysteretic model original formulation. The dependency of the degradation from the dissipated energy, distinctive feature of most of the revised versions of the model proposed in the past [4] has been kept in this model, though a novel expression of this quantity will be also introduced to overcome thermodynamic compatibility issues.

Parameter calibration and model validation have been performed on literature case-studies. Analyses have shown a satisfactory match between experimental response and numerical prediction.

Keywords: **Masonry, Macroelement, Hysteresis, Damage**

References

[1] Quagliarini, E., Maracchini, G., Clementi, F. (2017) Uses and limits of the Equivalent Frame Model on existing unreinforced masonry buildings for assessing their seismic risk: A review, *Journal of Building Engineering* **10**, 166–182.

[2] Liberatore, D., Addessi, D. (2015) Strength domains and return algorithm for the lumped plasticity equivalent frame model of masonry structures, *Engineering Structures* **91**, 167–18.

[3] Bouc, R., Forced Vibrations of a Mechanical System with Hysteresis, *Proceedings of the 4th Conference on Non-linear Oscillations*, Prague, 1967.

[4] Baber, T.T., Noori, M.N. (1985) Random Vibration of Degrading, Pinching Systems, Journal of Engineering Mechanics **111**,1010–1026.