Fast seismic vulnerability evaluation of historical masonry aggregates through local analyses: an adaptive NURBS-based limit analysis approach

Nicola Grillanda[1], Marco Valente[1], Gabriele Milani[1], Fabrizio Formigoni[2], Andrea Chiozzi[2] and Antonio Tralli[2]

[1] Department of Architecture, Built Environment and Construction Engineering (A., B., C.), Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan, Italy
e-mail: nicola.grillanda@polimi.it, gabriele.milani@polimi.it, marco.valente@polimi.it

[2] Department of Engineering, University of Ferrara, Via Saragat 1, 44122 Ferrara, Italy
e-mail: fabrizio.formigoni@student.unife.it, andrea.chiozzi@unife.it, tra@unife.it

ABSTRACT

Masonry structures represent one of the most common structural typologies in historical centers worldwide. Ancient historical centers in Italy constitute a wide part in the cultural heritage. Here, masonry buildings have been erected in continuity to each other. Thanks to the numerous integrations and addictions of new structural portions carried out during time, these structures result at now as aggregates of constructions.

The structural behavior of masonry aggregates can be difficult to identify. First of all, modifications performed during time make difficult to recover the documentation needed to achieve a complete knowledge of the aggregate. Secondly, the identifications of the quality of design details, such as connections between orthogonal walls and all the different masonry textures, is not always possible without a high number of invasive investigations. Finally, a diffused damage pattern is often observed, mainly given by soils settlements or previous seismic events, seriously affecting the horizontal load-bearing capacity of these structures. Therefore, a global response of masonry aggregates to horizontal actions is usually excluded. Recent seismic events in Italy (L'Aquila 2009, Emilia Romagna 2012, Center of Italy 2016) have put in evidence the high seismic vulnerability of masonry aggregates, showing a wide number of local failures.

In this work, an efficient computational tool aimed at studying masonry aggregates by means of local analyses is proposed. A NURBS (Non-Uniform Rational B-Spline) representation of geometry is adopted. NURBS entities, which are common in commercial CAD packages, have the great advantage to describe complex geometries (such as curved elements and walls with a high number of holes) with very few elements. An upper bound limit analysis formulation is implemented, in which the adopted NURBS elements are idealized as rigid bodies with dissipation allowed only along interfaces. The mesh of NURBS elements is progressively adjusted through a genetic algorithm in order to minimize the live load multiplier. Details about this method can be found in [1-2]. This procedure is applied in the evaluation of the horizontal load multiplier associated with the activation of local mechanisms during a seismic event.

Two case studies, a masonry aggregates located in the historical center of Arsita (Abruzzo region, Italy) and a row housing compound located in Sora (Lazio region, Italy) [3], are here presented. A quick evaluation of the seismic vulnerability is performed through the presented NURBS-based computational tool, showing the high importance of the local response in the study of the seismic behavior of masonry aggregates.

REFERENCES

[1] A. Chiozzi, G. Milani and A. Tralli, "A Genetic Algorithm NURBS-based new approach for fast kinematic limit analysis of masonry vaults", *Computers & Structures*, Vol **182**, pp. 187-204, (2017).

[2] A. Chiozzi, G. Milani, N. Grillanda and A. Tralli, "A fast and general upper-bound limit analysis approach for out-of-plane loaded masonry walls", *Meccanica*, Vol **53**(7), pp. 1875-1898, (2018).

[3] M. Valente, G. Milani, E. Grande and A. Formisano, "Historical masonry building aggregates: advanced numerical insights for an effective seismic assessment on two row housing compounds", *Engineering Structures*, Vol **190**, pp. 360-379, (2019).