Seismic performance assessment of masonry cross vaults through shaking table testing on a scaled model.

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ABSTRACT

Masonry cross vaults are among the most widely used typologies of horizontal structural elements for covering spaces of both ordinary and monumental buildings in the European countries. Their seismic vulnerability has been proved by systematic damages and collapses surveyed throughout the centuries. Therefore, the assessment of their structural safety is a crucial issue for the conservation and preservation of historical buildings. Although various methods have been developed and used to analyse both the stability (e.g. equilibrium method) and the dynamic behaviour (e.g. finite and discrete element approaches) of vaulted structures, experimental studies are constantly needed to validate and calibrate models. In this regard, limited experimental studies to understand the dynamic response of vaults have been done.

The present paper describes the results of shaking table tests on a 1:5 scaled cross vault model made of 3D printed blocks assembly with dry joints carried out at the Earthquake Engineering and Structural Dynamics testing room in the LNEC 3D shake table in Lisbon. The main aim of the tests is to investigate one of the most typical seismic damage for cross vaults, that is the shear failure. This type of mechanism frequently affects vaults of lateral aisles and it is mainly caused by a significant difference in stiffness of vaults' supports. Indeed, the lower stiffness of the central nave colonnade compared to the external wall may induce an in-plane shear distortion of the vault caused by a differential longitudinal displacement of its opposite sides. Incremental dynamic analyses are conducted up to collapse using two different types of seismic input: first, just the horizontal components of the ground motion signal are considered; then, also the vertical component is added. The results are analysed in terms of ultimate displacement capacity, modal parameters, crack pattern and damage mechanisms.

The experimental results obtained from the first set of tests (horizontal input) are compared with the results obtained from quasi-static tests performed on the same specimen by applying differential displacements at the vault's supports in terms of force/displacement capacity and damage mechanisms. The aim of this comparison is to stress the reliability of static analyses for the seismic assessment of this type of structures.

The results obtained from the second set of tests (horizontal and vertical input) will be compared, in the next future, with the results of an already programmed shaking table test on a full-scale masonry vaults, in order to understand the efficacy and reliability of small-scale models to understand the real vault's dynamic behaviour.

REFERENCES

[1] C. Casapulla, P. Jossa, and A. Maione, *Rocking motion of a masonry rigid block under seismic actions: a new strategy based on the progressive correction of the resonance response*, Ing. Sismica, vol. 27, no. 4, pp. 35–48, 2010.

[2] D. F. D'Ayala and E. Tomasoni, *Three-dimensional analysis of masonry vaults using limit state analysis with finite friction*, International Journal of Architectural Heritage, vol. 5, no. 2, pp. 140–171, 2011.

[3] A. Gaetani, G. Monti, P. B. Lourenço, and G. Marcari, *Design and Analysis of Cross Vaults Along History*, International Journal of Architectural Heritage, vol. 10, no. 7, pp. 841–856, 2016.

[4] M. Rossi,, C. Calderini., S. Lagomarsino. (2016). Experimental testing of the seismic in-plane displacement capacity of masonry cross vaults through a scale model. Bulletin of Earthquake Engineering, 14(1), 261–281.

[5] A. Tralli, C. Alessandri, and G. Milani, Computational methods for masonry vaults: A *review of recent results*, The Open Civil Engineering Journal, vol. 8, no. 1, pp. 272–287, 2014.

[6] E. Bertolesi, J. M. Adam, P. Rinaudo, and P. A. Calderón, 'Research and practice on masonry cross vaults – A review', *Eng. Struct.*, vol. 180, no. October 2018, pp. 67–88, 2019.