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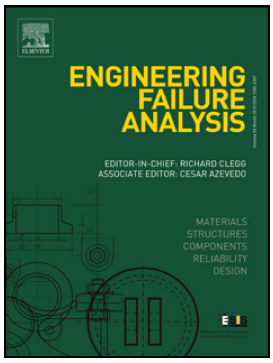

Seismic vulnerability evaluation of historic masonry churches: Proposal for a general and comprehensive numerical approach to cross-check results

A. Cundari, G. Milani, G. Failla

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Seismic vulnerability evaluation of historic masonry churches: Proposal for a general and comprehensive numerical approach to cross-check results

Cundari A.(1), Milani G.(2)*, Failla G.(1)

(1) Università Mediterranea di Reggio Calabria, Italy
(2) Politecnico di Milano, Italy
* Corresponding author

Abstract

The seismic vulnerability evaluation of existing masonry churches is an important issue in earthquake engineering. The Italian Guidelines for the built heritage suggest a quantitative assessment of vulnerability by means of technique that uses the upper bound theorem of limit analysis on 28 pre-assigned failure mechanisms, assuming masonry unable to withstand tensile stresses. In the framework of the kinematic theorem, the failure mechanism activating in reality is that associated to the lowest multiplier. Whilst the approach is very straightforward, it is intrinsically affected by possible inaccuracies, both because the real geometry of the church is accounted for only in an approximate way and the choice to limit the analysis to 28 mechanisms could exclude from computations the real mechanism occurring, with the consequent overestimation of the collapse acceleration.

In this paper a general approach relying into the collection of different numerical procedures is proposed to all practitioners interested in a precise estimation of the seismic vulnerability of masonry churches, with an indication of all the steps to follow to predict with fair accuracy their load carrying capacity. The approach comprises the determination of eigen-frequencies and modes, spectral analyses (both assuming an elastic behavior for masonry), limit analyses with FEM and pre-assigned failure mechanisms, pushover and non-linear dynamic computations. A case study is discussed in order to calibrate the procedure and discuss the actual accuracy of the results obtained.

Keywords: Masonry churches; Failure analysis under horizontal loads; Seismic vulnerability evaluation; Guidebook of different FE numerical procedures; collapse acceleration and failure mechanisms.

1 Introduction

The evaluation of the seismic vulnerability of masonry churches is a key issue in the preservation of the cultural heritage, especially for Italy where, basing on unofficial estimates, there could be more than 40000 worship buildings of any kind. The majority are obviously masonry churches. A correct estimation of their load carrying capacity against horizontal loads should be therefore considered mandatory to guarantee their safeguard, allowing focusing restoration interventions on the base of quantitative information and on the expected structural behavior in occasion of earthquakes. The seismic vulnerability of churches is generally high and it is mainly a consequence of some peculiar geometrical features (such as the presence of slender and long masonry walls, tympana and pinnacles), the low masonry tensile strength and the absence of enough stiff horizontal structural elements favoring the box behavior. According to post-earthquake surveys, the typical way churches fail is for the formation of partial collapse mechanisms activating well defined portions of the structures remaining stiff and roto-translating around cylindrical hinges [1]. At present, several advanced numerical approaches are available for single case studies in the technical literature [2]-[18], which however base in the majority of the case on complex FE discretization of the structure, which obviously is rarely available for common designers, which can use only general purpose commercial codes [19]-[21]. In addition, it seems that a more general approach to be used for any typology of church is not yet available.

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