

An integrated modelling approach to combine elastic amplification and rocking analysis of masonry collapse mechanisms

Anjali Mehrotra*, Andrew Liew[†], Philippe Block[‡] and Matthew J. DeJong*

* Department of Civil and Environmental Engineering
University of California – Berkeley, USA
email: mehrotra@berkeley.edu, dejong@berkeley.edu

[†]Department of Civil and Structural Engineering
University of Sheffield, UK
email: a.liew@sheffield.ac.uk

[‡]Block Research Group – Institute for Technology in Architecture
ETH Zurich, Switzerland
email: block@arch.ethz.ch

ABSTRACT

Failure of masonry structures under the influence of seismic action is a frequently observed phenomenon, with failure often occurring via specific, well-documented collapse mechanisms. Analysis of these collapse mechanisms is typically conducted using either simplified limit analysis, which tends to underestimate dynamic capacity, or more detailed numerical modelling strategies, which can be computationally-expensive and time-consuming. Alternatively, rocking dynamics, whereby equations of motion for the different collapse mechanisms are directly derived and solved, can be used. This approach has the advantage of being less computationally-demanding than most numerical models, while providing more accurate predictions than most simplified methods.

When assessing real structures, numerous collapse mechanisms should be considered, many of which involve partial collapse of the structure well above ground level. Thus, amplification and filtering of the ground motion by the building – which depends in turn on the natural frequency of the structure, needs to be considered. While the natural frequency and modes of simple, regular structures can be determined analytically, for most structures (e.g. bell towers, churches) consideration of the elastic response requires modal analysis using finite element models, the generation of which can be labour-intensive and time-consuming.

This paper presents a new integrated modelling approach which combines finite element analysis with rocking dynamics in order to model the seismic response of complex geometries in a computationally-efficient manner. The modelling strategy is implemented within *COMPAS* - an open-source computational framework which provides geometry processing independent of CAD software [1], and is incorporated within the broader framework of a tool being developed for the seismic collapse assessment of masonry structures [2]. To keep the solving strategy open-source, modal analyses are conducted using the *compas_fea* package [3], which directly constructs the FE model from the input geometry, and analyses it using the open-source finite element solver *OpenSees* [4]. The results of the modal analysis are subsequently used to define an equivalent single-degree-of-freedom oscillator, which is subjected to different ground motion records. The response of the oscillator is then scaled appropriately, with the scaled response serving as the input signal at the base of the rocking mechanism. The procedure can be repeated for a wide range of potential collapse mechanisms within a structure, in order to determine the most vulnerable mechanisms for a given suite of ground motions. The utility of this new modelling approach is finally demonstrated by applying it to the seismic assessment of a historic masonry tower in Italy.

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