Chapter 61
A Multi-Level Approach for the Numerical Modelling of Complex Monumental Buildings:
Seismic Assessment of the "Maniace Castle" of Syracuse

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ABSTRACT

Monumental buildings are characterized by elements (such as columns, vaults, arches …) that can suffer significant damage even under moderate earthquakes. Unfortunately, the available modeling approaches require a huge amount of computing resources. The chapter presents a multi-level strategy that is able to overcome these difficulties by a rational adoption of different computational approaches. As a case study, the non-linear seismic assessment of the medieval "Maniace Castle", in Syracuse (Sicily, Italy) is developed, by using different numerical models. First, the linear behavior of the building is studied by means of two 3D Finite Element models. Then, results are used to calibrate a 2D plane Rigid Body and Spring Model (RBSM), specifically formulated for approximating the macroscopic behavior of masonry texture with a small number of degrees of freedom. In order to account for the variability of the material characteristics, parametric non-linear analyses have been performed and compared.

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INTRODUCTION

Monumental buildings are characterized by the presence of peculiar geometric and architectural elements - such as facades, columns, vaults, arches … - that can suffer significant damage even under earthquakes of moderate intensity. On the other hand, the post-damage observation in recent earthquakes has shown, in some cases, an unexpected seismic resistance of historical buildings. In order to provide a deep understanding of the available seismic capacity, it is fundamental to provide reliable modelling approaches and methods of analyses. This is particularly important also in view of the peculiar needs of conservation of the architectural heritage. In fact, the design of earthquake-resistant interventions should be aimed at balancing the requirements of safety with those of preservation, and pursuing the following objectives: a) avoiding a possible underestimate of the structural capacity that would involve invasive retrofitting interventions; b) modelling possible alternatives for retrofitting, and comparatively appraising the acceptability in terms of risk reduction/compatibility (Asteris, 2008; Asteris et al., 2014; Binda & Saisi, 2005; Modena, Valluzzi, Da Porto, & Casarin, 2011; Valluzzi, 2007; Valluzzi, Binda, & Modena, 2002).

In general, it is necessary to perform a long and complex procedure: assessment of the safety level of the building in the actual conditions; selection of the different available options for the intervention; assessment of the safety level of the building for each of the retrofitting options; comparison and critical evaluation of the effectiveness in terms of increase of the safety level and invasiveness. Moreover, the above mentioned steps should be repeated for many different levels of the seismic input, according to the seismic hazard of the site and the different limit states provided for the design. The structural analysis might be performed by adopting different methods: linear/non-linear static or dynamic methods, each of which presents different levels of difficulty and provides different information.

In the chapter, a multi-step strategy is applied to the seismic analysis of an Italian monument: the medieval "Maniace Castle"', in Syracuse (Sicily, Italy). Three different numerical models are implemented:

1. A global three-dimensional finite element model of the whole castle;
2. A detailed three-dimensional finite element model of the part of the building that suffers the main static problems;
3. A two-dimensional rigid element model on which advanced dynamical analyses are performed, by considering the degradation of the material subjected to cyclic loading (Casolo, 2009).

The objective of the study was to apply a rational approach to the structural analysis of a complex monument, in which information is obtained at different scales and levels of detail, in order to provide a general comprehension of the seismic behavior and, at the same time, investigate some critical aspect of the response of masonry buildings under seismic loads: relevant non-linearity, hysteretic dissipation, development of damage, effect of anisotropy and masonry texture. The multi-level approach allows to identify the parts of the building that are more at risk. On these parts, advanced techniques of modelling and analysis are implemented, allowing to balance the need of accuracy against efficiency in terms of computational effort. The final objective is to assess the actual seismic vulnerability of the Monument and rationally identify preliminary guidelines for the structural retrofitting intervention.