Non-destructive Testing and Numerical Modelling for the Seismic Evaluation of Historic Buildings

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Abstract
Natural hazards have caused a significant number of disasters in the last decades. These events lead to important economic impacts, deaths and irrecoverable losses. In this matter, the earthquakes have a significant contribution, in which the collapse of existing masonry is common. Besides the direct losses associated with the collapse and repairing/reconstruction of buildings, there are also indirect losses, such as the irrecoverable loss of historic buildings that represent the identity of the cities and the economic impact caused by a reduction in the tourism sector. The evaluation of the seismic performance of historic buildings requires a specific methodology, in which the inspection and non-destructive testing correspond to the first works to carry out and are fundamental to guarantee a reliable assessment. In general, the inspection aims to perform the damage and geometry survey, which can be supported by techniques and equipment such as photogrammetry, laser scanner, drone and borescope camera. The non-destructive testing does not cause damage to the building and allows to identify: (1) no-visible elements; (2) different types of materials and conservation status; (3) damage; (4) interventions carried out in the past; (5)steel elements and ducts. Moreover, this type of tests allows to estimate the material and geometric properties. Different types of non-destructive testing can be used, such as sonic and ultrasonic tests, impact-echo test, ground penetrating radar testing and dynamic identification tests. The numerical modelling of historic structures can be evaluated using models based on the following main modelling strategies: (1) continuum models based on the macro-modelling approach; (2) models based on the discrete-modelling approach; (3) models based on rigid macroblocks; (4) models based on the structural elements. The evaluation of the seismic performance of historic buildings can be carried out using two main types of non-linear analysis: (1) static analysis (limit analysis, pushover analysis); (2) dynamic analysis (non-linear dynamic analysis with time integration and application of accelerograms at the base). In general, and for large structures such as monuments, the seismic performance is evaluated through the limit analysis based on the kinematic theorem and the pushover analysis with continuum models based on the macro-modelling approach (Finite Element Method - FEM). The Discrete Element Method (DEM) is also used to evaluate the seismic performance of historic buildings, mainly using partial models of the structure. The application of the experimental and numerical techniques for historic buildings is presented, namely for the Monastery of São Miguel de Refojos (Portugal), Church Ruins of the Carmo Convent (Portugal), San Sebastian Basilica (Philippines) and Kûnû Tambo Church (Peru).