ROMA TRE UNIVERSITÀ DEGLI STUDI

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DEPARTMENT OF CIVIL, COMPUTER AND AERONAUTICAL ENGINEERING
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MSc Course in Civil Engineering for natural risk protection
Laurea Magistrale in ingegneria Civile per la protezione dai rischi naturali

MSc Degree Thesis
Tesi di Laurea Magistrale

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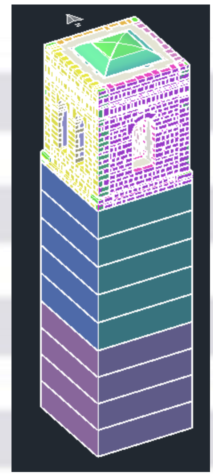
Stage: INTERNAL

July 2025

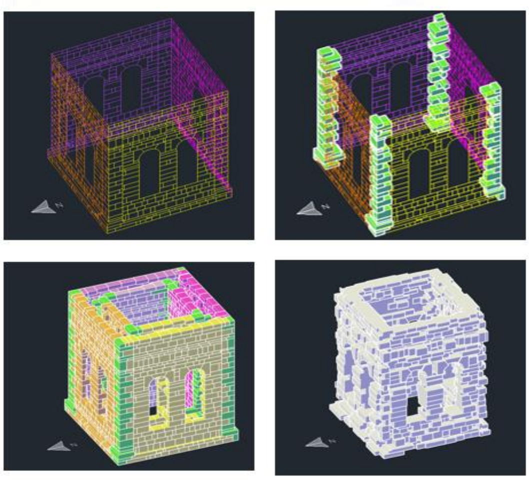
Structural analysis with discrete elements of the bell tower of the Basilica of Santa Maria della Quercia (VT): from digital survey to monitoring-based calibration



Motivations and aims

Discrete Element Modelling (DEM) is increasingly recognized as a key tool for analyzing historic masonry structures, due to its ability to simulate mechanical behavior by representing the interaction between individual blocks. This "brick-by-brick" approach allows for a more accurate understanding of collapse mechanisms and crack propagation, overcoming the limitations of continuous models. When applied to heritage buildings, DEM can effectively integrate high-resolution digital survey data and provide a reliable basis for vulnerability assessment and targeted conservation strategies.

Methods and results



This thesis aims to develop a numerical model of the bell tower of the Basilica of Santa Maria della Quercia, addressing the specific challenges related to the historical construction technique of cavity wall masonry. The complex internal composition and limited accessibility of the core make both modeling and mechanical characterization particularly challenging. The entire work is based on an integrated approach, starting from advanced digital surveying techniques used to precisely capture the geometry and condition of the structure. The ultimate goal is to calibrate the numerical model based on data from a dynamic monitoring campaign conducted through Operational Modal Analysis. The experimental modal parameters were used within a Bayesian optimization process, thus enabling a reliable simulation of the tower’s structural response.

Conclusions and future developments

The calibration process yielded good results for the validation of the numerical model. Comparisons between the numerical response spectra and the monitoring data, expressed in terms of normalized power spectral density (NPSD), showed low errors. Even at the control points used for the assessment, the results were satisfactory, confirming the reliability of the model in reproducing the dynamic behavior of the structure. The model can be used for more accurate predictive analyses, seismic vulnerability assessments, and simulations of structural strengthening interventions, thus becoming a key tool to support the preservation and management of historical heritage.