Reduction of the seismic vulnerability of historical masonry structures: Numerical and experimental analyses

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Summary

The seismic assessment and retrofitting of existing masonry structures are becoming increasingly important in earthquake-prone regions with a significant presence of built cultural heritage. Hence, reliable numerical models are essential to designing retrofitting solutions effectively. Although micro-modelling methods offer higher accuracy for these irregular and complex structures, they require significant computational resources, expertise, and the definition of generally unknown mechanical parameters. Simplified modelling methods have been developed to adequately represent the behaviour of masonry buildings, leaving the use of more detailed modelling for local particularities that are not adequately represented with macro-modelling methods.

This study proposes simplified modelling approaches using the Equivalent Frame (EF) method to address specific challenges in complex historical masonry monuments. The National Palace of Sintra in Portugal, consisting of irregular and complex aggregate buildings, serves as a case study. The results of nonlinear static analyses obtained with an automatically generated mesh were compared with those from a manually refined model, which is often necessary due to the high irregularity of historical buildings. Models with varying degrees of connections between structural units were also developed and compared. Moreover, a transverse arch commonly found in historical monuments was modelled, and the numerical results were validated against experimental data.

When structural safety is not verified, it becomes necessary to design appropriate retrofit solutions, adopting compatible materials like composites and lime-based mortars. Nevertheless, despite the importance of the topic, many composite-based material solutions still lack in-depth studies to characterise the improved behaviour of retrofitted masonry. For this reason, two extensive experimental programs were designed to characterise the seismic behaviour of retrofitted stone masonry using compatible solutions such as Fibre-Reinforced Cementitious Matrix (FRCM) systems, Composite Reinforced Mortars (CRM) systems, and mortar injection. Results include ratios of the enhancements in the resistance and deformation capacity of retrofitted masonry.

Keywords

Historical complex masonry buildings; Nonlinear seismic assessment; Seismic retrofitting; Equivalent Frame model; Quasi-static cyclic shear compression test.

Quasi-static cyclic test setup on a rubble stone wall.