Seismic Damage Mechanisms for Churches and Damage Sequence: Considerations from a Case Study

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ABSTRACT

The many earthquakes that have occurred in Italy in the last decades have caused considerable damage and losses to the architectural heritage and particularly to masonry churches, especially subject to seismic damage due to their structural characteristics. These circumstances have brought to study specific methods for analysis of damage and of seismic vulnerability [1], as well as to assess the validity of interventions for damage repair and for improvement of the seismic response capability.

The method of limit equilibrium has proven to be a powerful tool for both damage and vulnerability analysis. The abacus of possible limit mechanisms that recur in the church structural components is founded on a very ample base of observational data and has become a widely used reference in rapid assessment as well as in more detailed analyses. To this purpose, the post-earthquake observation and analysis of damage cases remains a fundamental step for improving this additive knowledge.

Within this context, the damage occurred to a church during the Pianura Padana Earthquake of 2012 [2]is interpreted. The church, built in the 18th century and located in a village in the Mantua province, presented extended damage in different areas, especially in the vaults covering the three naves. The form of damage reproduced, indeed, situations listed in the abacus of mechanisms. The church façade, with an imposing tympanum according to the style of the time, instead, reported only initial damage indicating an out-of-plane rotation of the tympanum, as well as a rotation of the entire façade.

Earthquake recordings were available in the vicinity of the church for the two major shocks that characterized the earthquake. On this basis the seismic response of the church has been analysed with different approaches, with complete and with partial models that allowed an appreciable understanding of the global behaviour and of the modality of damage development, in relation to the first and to the second shock.

For the façade, however, the analysis of limit equilibrium had indicated out-of-plane failure of the tympanum as the first mechanism to develop. The real outcome was better interpreted by a time-history non-linear analysis, that showed the evolution of damage from the initial involvement of the tympanum subsequently controlled by the establishing of a global façade mechanism. The study has suggested some considerations on the cases where the sequence of damage may influence the outcome.

REFERENCES

[1] S. Lagomarsino, S. Podestà, "Seismic vulnerability of ancient churches: part 1. Damage assessment and emergency planning", *Earthquake Spectra* **20**(2), 377-394, (2004).

[2] L. Sorrentino, L. Liberatore, L. D. Decanini, D. Liberatore, "The performance of churches in the 2012 Emilia earthquakes", *Bulletin of Earthquake Engineering* **12**, 2299–2331, (2014).