buildings

Editorial

Seismic Performance Assessment of Buildings

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The seismic performance assessment of buildings is a challenging process. Despite the valuable guidelines in force for the seismic assessment of buildings, including the Eurocode 8 part 3 [1] and the Italian Technical Code [2,3] in Europe, FEMA 273/274 [4] in the US, and the New Zealand Society of Earthquake Engineering (NZSEE) Seismic Assessment guidelines [5] in New Zealand, several open issues require attention from the scientific community. This Special Issue provides an overview of the present knowledge related to various aspects of "Seismic Performance Assessment of Buildings" and identifies further studies needed concerning this area of research. A total of seven original research studies were published, with relevant contributions from international experts from Italy, Portugal, Switzerland, and New Zealand. The contributions address the seismic assessment of reinforced concrete (RC) wall buildings, RC buildings at urban scale, residential unreinforced masonry (URM) buildings, including timber diaphragms and structural irregularities, complex monumental URM buildings, and adobe buildings.

Orumiyehei and Sullivan [6] propose a newly simplified probabilistic displacement-based assessment approach for RC wall buildings. The approach is a simplification of the traditional displacement-based assessment approach as it reduces the steps required to compute damping and spectrum reduction factor, and it is converted into a probabilistic approach by accounting for pertinent variabilities to assess the building's seismic risk in terms of the annual probability of exceeding key limit states. To evaluate the accuracy and limitations of the proposed approach, a series of RC buildings with 4-, 8-, and 12-stories were assessed by comparing the assessed likelihood of exceeding key limit states obtained from the simplified and rigorous (multi-stripe analyses) probabilistic approach. The results indicate that the former approach provides good estimates of the median intensity associated with exceeding a given failure mechanism and the annual probability of exceeding limit states. This newly simplified probabilistic displacement-based assessment approach for RC wall buildings is perceived as a valuable extension to the displacement-based assessment method considered in the current assessment guidelines in New Zealand [5].

Flora et al. [7] proposes a novel simplified approach for the seismic loss assessment of RC buildings at urban scale based on the direct estimation of expected annual loss (DEAL) method, which aims to provide a general understanding of the socio-economic impacts of seismic scenarios at a territorial scale. The simplified approach was applied to the residential building stock of two main areas of the center of Potenza (Italy). Non-linear static analyses (NLSA) were carried out in a series of case-study buildings (archetypes), each one associated with the main RC structural typologies identified, to derive the main engineering demand parameters (EDPs), which represent the input data for the application of the DEAL method and the estimation of the EAL (expected annual loss) of RC buildings. The EAL associated with indirect losses related to downtime was also estimated based on the method presented in Cardone et al. [8]. With the results in terms of monetary losses, preliminary considerations on the economic and social impacts of probable seismic scenarios were made.

Aşıkoğlu et al. [9] present an overview of the NLSA procedures within the framework of the performance-based approach for URM with structural irregularity. The authors highlight two major issues: (1) the lack of a systematic and uniform procedure for defining structural irregularities in masonry buildings and (2) the applicability of classical NLSA procedures to irregular masonry buildings, as these were developed for regular buildings. Two masonry case studies with different irregularity levels were selected from the literature to exemplify the application of different NLSA. It was demonstrated that the maximum displacement demand was highly dependent on the empirical formulations, stressing the concerns about the application of both classical and extended (improved so that the effects of irregularities on the response can be included) NLSA procedures. The main purpose of the review was to point out the complexity of structural irregularities and their influence on the procedures adopted to achieve performance limits and to show, to a great extent, that further studies are still needed concerning the applicability of NLSA procedures to irregular masonry buildings.

Guerrini et al. [10] compare different methods for calculating earthquake-induced displacement demands associated with NLSA procedures to assess URM buildings. The methods considered in this study are divided into two main families: methods based on the concept of equivalent linear systems and methods that employ inelastic response spectra. First, the authors discuss the accuracy of two established methods per family, highlighting their main shortcomings, and then present an improved formulation for each family, the optimal stiffness method (OSM) and the modified N2 method (MN2 method). The accuracy of the improved formulations was assessed based on the results from non-linear time-history analyses (NLTHA), carried out on single-degree-of-freedom oscillators with hysteretic force–displacement relationships representative of URM buildings. It was concluded that both proposed formulations predict the median ductility demand accurately while limiting the dispersion of the results.

Tomić et al. [11] explore the seismic assessment of URM buildings with timber diaphragms by explicitly modeling the diaphragm stiffness and the finite strength of wall-to-diaphragm connections through a newly developed equivalent frame macro-element proposed by Vanin et al. [12] able to simulate both in-plane and out-of-plane behavior of URM buildings. The modeling approach was used to model an unstrengthened stone masonry building, experimentally investigated through a shake table (Pavia Building 1 [13,14]), and to simulate three retrofit interventions: (1) diaphragms retrofitted with an additional layer of timber planks, (2) retrofitted wall-to-diaphragm connections, and (3) the combination of both interventions. Based on these simulations (unstrengthened and strengthened), the authors validated the new modeling approach for the seismic assessment of URM buildings with unstrengthened timber floors and showed that strengthening the timber diaphragm alone is ineffective when the friction capacity of the wall-to-diaphragm connection is exceeded. This puts in evidence the importance of explicitly modeling the diaphragm stiffness and the finite strength of wall-to-diaphragm connections if the equivalent frame model captures both global in-plane and local out-of-plane failure modes.

Lagomarsino et al. [15] address the seismic assessment of the Podestà Palace in Mantua (Italy), highlighting the main issues with the assessment of complex monumental URM buildings composed of various units stratified over centuries. The authors propose an integrated use of three modeling strategies characterized by a different computational effort and degree of accuracy to: (1) assess the global response of the whole structure and estimate the mutual dynamic interactions among the structural units, (2) assess the out-of-plane response of facades prone to the activation of local mechanisms, and (3) deepen the seismic response of some critical parts. This integrated approach uses the results achieved from one modeling approach as input for another (e.g., the floor spectra estimated by (1) were used to define the seismic input in (2)). This aimed to get a comprehensive interpretation of the seismic behavior of Podestà Palace and to address more rationally possible strengthening solutions, parametrically investigated and specifically conceived for the safety and preservation of the monument.

Momin et al. [16] approach the seismic vulnerability assessment of Portuguese adobe buildings as part of the endeavor towards the preservation of the inheritance and cultural heritage of the country. Three buildings with one-story, two-stories, and two-stories plus an attic were numerically modeled using solid and contact elements. NLTHA was performed until complete collapse occurred. Two novel EDPs were used: the crack propagation ratio (CPR), which refers to the cracks that develop in the walls prior to the onset of the detachment of the blocks, and the building volume loss ratio (VLR), which refers to the post-failure movements of the blocks that have the potential to cause fatalities. According to the authors, the choice of the building VLR is considered a better damage descriptor for estimating risk to occupants as compared to traditional damage states because it can be directly correlated with earthquake fatalities. The authors also proposed damage thresholds in correlation with the damage classifications of the European Macroseismic Scale (EMS-98) [17]. The seismic vulnerability assessment was concluded with the derivation of fragility functions using cloud analysis to quantify physical, structural damage due to a given intensity measure (IM). In this case, the peak ground acceleration (PGA) was chosen for fatality vulnerability functions to estimate indoor fatalities.

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References

1. CEN. *Eurocode 8: Design of Structures for Earthquake Resistance-Part 1: General Rules, Seismic Actions and Rules for Buildings*; CEN: Brussels, Belgium, 2005.
2. NTC 2018. Italian Technical Code, Decreto Ministeriale 17/1/2018. Aggiornamento Delle Norme Tecniche per le Costruzioni. Ministry of Infrastructures and Transportation, G.U. n.42 of 20/2/2018. Available online: https://www.studiopetrillo.com/ntc2018.html (accessed on 20 September 2021). (In Italian)
3. Ministry of Infrastructures and Transportation. C.S.Ll.PP. n.7 del 21/01/2019. Istruzioni per L'Applicazione Dell'Aggiornamento delle Norme Tecniche per le Costruzioni di cui al D.M. 17/01/2018 G.U. S.O. n.35 of 11/2/2019. Available online: https://www.gazzettaufficiale.it/eli/id/2019/02/11/19A00855/sg (accessed on 20 September 2021). (In Italian).
4. Federal Emergency Management Agency (FEMA). *NEHRP Guidelines for the Seismic Rehabilitation of Buildings and Commentary*; FEMA: Washington, DC, USA, 1997; pp. 273–274.
5. New Zealand Society of Earthquake Engineering (NZSEE). *The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments*; Part C—Detailed Seismic Assessment; NZSEE: Wellington, New Zealand, 2017.
6. Orumiyehei, A.; Sullivan, T.J. Displacement-Based Seismic Assessment of the Likelihood of Failure of Reinforced Concrete Wall Buildings. *Buildings* **2021**, *11*, 295. [CrossRef]
7. Flora, A.; Cardone, D.; Vona, M.; Perrone, G. A Simplified Approach for the Seismic Loss Assessment of RC Buildings at Urban Scale: The Case Study of Potenza (Italy). *Buildings* **2021**, *11*, 142. [CrossRef]
8. Cardone, D.; Flora, A.; Picione, M.D.L.; Martoccia, A. Estimating direct and indirect losses due to earthquake damage in residential RC buildings. *Soil Dyn. Earthq. Eng.* **2019**, *126*, 105801. [CrossRef]
9. Aşıkoğlu, A.; Vasconcelos, G.; Lourenço, P.B. Overview on the Nonlinear Static Procedures and Performance-Based Approach on Modern Unreinforced Masonry Buildings with Structural Irregularity. *Buildings* **2021**, *11*, 147. [CrossRef]
10. Guerrini, G.; Kallioras, S.; Bracchi, S.; Graziotti, F.; Penna, A. Displacement Demand for Nonlinear Static Analyses of Masonry Structures: Critical Review and Improved Formulations. *Buildings* **2021**, *11*, 118. [CrossRef]
11. Tomić, I.; Vanin, F.; Božulić, I.; Beyer, K. Numerical Simulation of Unreinforced Masonry Buildings with Timber Diaphragms. *Buildings* **2021**, *11*, 205. [CrossRef]
12. Vanin, F.; Penna, A.; Beyer, K. A three-dimensional macroelement for modelling the in-plane and out-of-plane response of masonry walls. *Earthq. Eng. Struct. Dyn.* **2020**, *49*, 1365–1387. [CrossRef]

13. Magenes, G.; Penna, A.; Galasco, A. A full-scale shaking table test on a two-storey stone masonry building. In Proceedings of the 14th European Conference on Earthquake Engineering, Ohrid, North Macedonia, 30 August–3 September 2010.
14. Magenes, G.; Penna, A.; Senaldi, I.E.; Rota, M.; Galasco, A. Shaking table test of a strengthened full-scale stone masonry building with flexible diaphragms. *Int. J. Archit. Herit.* **2014**, *8*, 349–375. [CrossRef]
15. Lagomarsino, S.; Degli Abbati, S.; Ottonelli, D.; Cattari, S. Integration of Modelling Approaches for the Seismic Assessment of Complex URM Buildings: The Podestà Palace in Mantua, Italy. *Buildings* **2021**, *11*, 269. [CrossRef]
16. Momin, S.; Lovon, H.; Silva, V.; Ferreira, T.M.; Vicente, R. Seismic Vulnerability Assessment of Portuguese Adobe Buildings. *Buildings* **2021**, *11*, 200. [CrossRef]
17. Comisión Sismológica Europea. Escala Macro Sísmica Europea EMS-98. 1998, Volume 15. Available online: http://media.gfz-potsdam.de/gfz/sec26/resources/documents/PDF/EMS-98_Original_englisch.pdf (accessed on 20 September 2021).