frontiers | Frontiers in Built Environment

TYPE Editorial
PUBLISHED 10 November 2022
DOI 10.3389/fbuil.2022.1074273

Editorial: Smart passive damper design for building structures with higher resilience under uncertain earthquake ground motions

Dario De Domenico[1]*, Solomon Tesfamariam[2] and Xinzheng Lu[3]

[1]Department of Engineering, University of Messina, Messina, Italy, [2]School of Engineering, The University of British Columbia, Kelowna, BC, Canada, [3]Key Laboratory of Civil Engineering Safety and Durability of Ministry of Education, Tsinghua University, Beijing, China

OPEN ACCESS

EDITED AND REVIEWED BY
Ehsan Noroozinejad Farsangi,
University of British Columbia, Canada

*CORRESPONDENCE
Dario De Domenico,
dario.dedomenico@unime.it

SPECIALTY SECTION
This article was submitted to Earthquake Engineering,
a section of the journal
Frontiers in Built Environment

RECEIVED 19 October 2022
ACCEPTED 21 October 2022
PUBLISHED 10 November 2022

CITATION
De Domenico D, Tesfamariam S and Lu X (2022), Editorial: Smart passive damper design for building structures with higher resilience under uncertain earthquake ground motions.
Front. Built Environ. 8:1074273.
doi: 10.3389/fbuil.2022.1074273

KEYWORDS

earthquake-resilient design, robust optimization, passive damper, uncertainty analysis, supplemental energy dissipation devices, damper optimization, performance-based seismic engineering

Editorial on the Research Topic
Smart passive damper design for building structures with higher resilience under uncertain earthquake ground motions

Existing and new building structures located in earthquake-prone areas are vulnerable to damage. One strategy to protect these structures is to incorporate supplemental energy dissipation devices, in the form of hysteretic, viscous, or inertial dampers. In the last few years, these devices demonstrated their capability to limit earthquake-induced damage, thus implying minimal downtime and affordable repair cost in both ordinary and strategic/critical building structures. However, the efficiency of such devices strongly relies on their appropriate placement in the building structure as well as in selecting their constitutive parameters. Another open issue is how to incorporate the uncertain nature of seismic excitation within a robust design framework. A smart design strategy using passive dampers should account for the peculiar characteristics of the structure and should aim at achieving multi-level performance requirements under different levels of excitation through robust multi-objective optimization.

Based on these motivations, this Research Topic has collected seven papers after a detailed and rigorous peer-review process. The papers deal with smart passive damper design that explicitly incorporates the uncertainty of the seismic excitation or structure, simultaneous optimal design of main building structures and dampers under critical seismic excitation, innovative energy dissipation technologies, and hybrid dampers for an improved earthquake-resilient building design and smart damper optimization under long-period pulse-type ground motions of extremely large amplitudes.

Hashizume and Takewaki examined the performance of a novel hysteretic-viscous hybrid (HVH) damper system for the seismic protection of tall buildings. The system combines a large-stroke viscous damper with a hysteretic damper equipped with a gap mechanism as a stopper. The proposed system was adopted to mitigate catastrophic effects caused by long-period pulse-type earthquake ground motions of extremely large amplitudes, which may be particularly critical for high-rise and base-isolated buildings with a long natural period. The authors used a double impulse as representative of the main part of pulse-type ground motions of extremely large amplitude. The HVH damper system proved to be an effective strategy to reduce the catastrophic effects of this kind of seismic excitation on tall buildings and exhibited a comparable performance to a formerly proposed dual hysteretic damper (DHD) system composed of parallel-type small and large-amplitude hysteretic dampers.

Ishida and Takewaki further explored the optimal design of the previously described HVH damper system when implemented in nonlinear building frames for simultaneous reduction of inter-story drift and acceleration. Although the HVH is effective in mitigating the deformation response (inter-story drift), as a counter effect, it increases the acceleration response when the gap mechanism becomes active (stiffness starts working). For this reason, a compromise between the reduction of maximum inter-story drift and maximum acceleration was sought by the authors. A combined index performance parameter was introduced that simultaneously accounts for maximum inter-story drift and maximum acceleration, which was minimized to obtain the optimal gap quantity of hysteretic dampers with gap mechanisms for various input velocity levels and various hysteretic damper stiffness ratios.

Fujita et al. investigated the optimal damper placement for building structures under the resonant critical double impulse, as representative of actual earthquake ground motions. In this work, the authors incorporated the influence of uncertain characteristics of linear and bi-linear oil dampers and of stiffness of the building frame on the resulting building structural safety. A robust optimization method was proposed by changing the second impulse timing, thus considering inherent uncertainties in input seismic excitation. Moreover, a novel objective function was conceived to enhance structural performance and robustness. Numerical examples on 10- and 20-story planar building frames demonstrated higher robustness of the structural performance by using the proposed approach as compared to an alternative, ordinary optimal damper placement without considering uncertainties.

Takewaki and Akehashi presented a comprehensive and systematic review of the optimal and smart design of nonlinear building structures with and without passive dampers subjected to earthquake loading. Different aspects were discussed in this review through a sixfold categorization approach: 1) the optimal design of bare nonlinear building frames under seismic loading; 2) the optimal design of nonlinear dampers for elastic building frames under seismic loading; 3) the optimal design of linear dampers for nonlinear building frames under seismic loading; 4) the optimal design of nonlinear building frames with specified nonlinear dampers under seismic loading; 5) the optimal design of nonlinear dampers for specified nonlinear building frames under seismic loading; and 6) the simultaneous optimization of elastic-plastic building structures and passive dampers. This categorization provided an overview of how literature studies are advancing gradually by accounting for nonlinear responses, and also introduced another classification in view of solution strategies proposed by researchers, including mathematical programming approaches, optimality criteria approaches, metaheuristic approaches, and a combined approach of the sensitivity-based procedure and the optimality criteria.

Uemura et al. addressed the global simultaneous optimization of oil, hysteretic, and inertial dampers for building structures using a real-valued genetic algorithm and local search. By means of the proposed simultaneous optimization method, structural designers are given the possibility of selecting the optimal proportion of these three dampers based on cost and performance requirements. Displacement and acceleration response can be reduced well by oil dampers without implying significant changes in natural frequencies, while hysteretic dampers reduce displacement but may increase acceleration response. Finally, inertial dampers can lengthen the natural periods with negative stiffness and reduce the maximum acceleration but, as a counter effect, may lead to some undesired increase of deformation. Considering these particular aspects of each damper, the authors used a real-valued genetic algorithm optimization algorithm to attain a globally optimal solution. A multi-objective optimization for deformation and acceleration was also investigated. It was demonstrated that the proposed approach leads to the best solution by involving a relatively short computational time (a smaller number of time-history response analyses than an alternative sensitivity-based algorithm).

Akehashi and Takewaki presented a new method for the simultaneous optimal design of main building structures and viscous dampers for elastic-plastic building structures under critical double impulse. By assuming the maximum inter-story drift as the objective function, the most inactive story stiffness and damper damping coefficients were sequentially eliminated in the optimal design procedure. It was demonstrated that the proposed sensitivity-based design algorithm is effective irrespective of the target value of the sum of damper damping coefficients and the input level of the critical double impulse. In particular, by the numerical analyses presented, it emerged that the proposed design method enables the high yield-strength design with effective seismic energy absorption and the high limit-strength design effective for extremely large disturbances.

Kawai and Takewaki investigated the critical response of a multi-story damped bilinear hysteretic shear building model under a multi-impulse representative of long-period, long-duration earthquake ground motions. The critical input timing of the multi-impulse was identified as the time in which the story shear force (sum of the restoring force and the damping force) in the first story attains zero in the unloading process. A so-called Multi Impulse Pushover (MIP) was introduced to perform a comprehensive performance evaluation for increasing input levels. In the MIP, once the critical time interval between impulses in the multi-impulse was found for a specific input level, the input level is increased gradually and a new critical timing is determined. This procedure is repeated until reaching the desired input level. The performance evaluation was conducted in terms of energy response indicators and compared to the response under a sinusoidal wave to demonstrate the usefulness of the adopted multi-impulse as a substitute for sinusoidal waves.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Acknowledgments

We would like to thank all authors for their valuable contributions, the dedicated reviewers for their useful guidance and suggestions for improving the papers, and the Editorial Team of *Frontiers in Built Environment* (“Earthquake Engineering” section) for the professional assistance and for giving us the valuable opportunity to launch this Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher’s note