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Editorial: Energy-based seismic engineering

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Editorial on the Research Topic
Energy-based seismic engineering

A traditional force-based approach has been used for decades for the seismic design of structures mainly due to its simplicity and its close relation with the way the other types of lateral loads, e.g., wind, are tackled. However, characterizing the seismic loading effect in terms of forces lacks rationality since the forces are not the product of the earthquake but of the resistance of the structure. A set of lateral forces is unable to represent the damage potential of an earthquake beyond the elastic limit of the structure. At the beginning of this century, the Vision 2000 committee devised two approaches to overcome the inconsistencies of the Force Based Design (FBD): the Displacement Based Design (DBD) and the Energy Based Design (EBD). DBD approach took the lead and has been implemented in most seismic codes. DBD is a step forward in the right direction because it directly addresses the non-linear response of the structure by using displacements instead of forces. However, this simple way to address the problem ignores the cyclic nature of the seismic loading and of the structural response. DBD cannot address explicitly a key aspect of the seismic response: the cumulative damage. The plastic strain energy accumulated through hundreds of cycles of deformation in the structural elements is, together with the maximum apparent displacements and the associated second order effects, what determines the level of damage in the structure and its proximity to collapse. Cumulative damage is particularly important in existing structures and in evaluating the effects of sequences of earthquakes. Regarding the former, a large number of existing buildings in the world were built under poor seismic standards or without standard; they are highly vulnerable to earthquakes. Recent studies unveiled that 40% of the build-up in Europe were built before 1960 (Negro et al., 2020) and most of them are prone to severe damage even under moderate earthquakes (Palermo et al., 2018). As for the later, recent worldwide earthquake events have highlighted the need to account for the effects of sequential earthquake-induced ground shaking (Iacoletti et al., 2023). Both problems are receiving increased attention and the energy-based approach has a great deal to say about them.

The energy-based approach makes a straightforward use of the energy conservation (balance) law. Compared to forces and displacements, energy is apparently a more difficult concept for a designer to rationalize. However, the energy balance is a solid law of nature as familiar to engineers and easy to apply as equilibrium in FBD, or as the geometric continuity in the deformed structure in case of the DBD. The energy-based approach has many advantages (Fardis, 2018). The first and

most important one is that the energy input by a given earthquake per unit mass depends almost exclusively on the structure's fundamental period and is roughly independent of the viscous damping ratio, the post-yield hysteretic behavior, the degree of inelastic action and the number of degrees of freedom of the system. Second, the true response of a structure subjected to concurrent shaking in both horizontal directions and the associated damage are better described by a scalar measure, such as energy, than in terms of vectors, such as forces or displacements, obtained separately in two arbitrarily chosen directions and combined with approximated empirical rules. Third, energy embodies more damage-related-information than displacements.

The papers in this Research Topic focus on the theme of energy-based approach, the intent being to provide several recent developments and research activities on this Research Topic.

The paper "*Correlation Between Wavelet-Based Energy Parameter and Observational Damage Degrees for Gravity Design Building During the May 2018 Mayotte Seismic Crisis*" studies the damage caused by a series of earthquakes on structures designed without seismic codes or with low seismic codes. The damage is estimated in terms of dissipated energy using wavelet transform and correlated with the observations.

The paper titled "*Energy-based procedures for seismic fragility analysis of mainshock-damaged buildings*" delves in the same vein and focusses on energy-based engineering demand parameters that explicitly account for cumulative damage to consider the effects of ground-motion sequences.

The paper "*Correlation between energy and displacement demands for infilled reinforced concrete frames*" investigates the role of masonry infills in the seismic response of relatively weak reinforced concrete structures. The importance of the contribution of masonry infills in reducing both dissipation and displacement energy demands in frame elements is clarified.

The paper "*Influence of the constitutive model in the damage distribution of buildings designed with an energy-based method*" sheds light on another key aspect of the energy-based seismic design methods: the distribution of the cumulative plastic strain energy among stories.

The paper "*Energy-based response prediction of reinforced concrete buildings with steel damper columns under pulse-like ground motions*" studies the accuracy of the energy-based approach in predicting the peak response of RC frame buildings with steel damper columns subjected to pulse-like ground motions.

Finally, the paper "*Explicit overturning limit of rigid block using triple and pseudo-triple impulses under critical near-fault ground motions*," focusses on the rocking behavior of rigid blocks. This Research Topic is important in the evaluation of the earthquake response of monuments, furniture, slender structures or base-isolated high-rise buildings with isolators that do not have tensile resistance. The problem is addressed using the conservation law of energy.

Author contributions

FM: Conceptualization, Writing–review and editing. AB-C: Conceptualization, Data curation, Writing–original draft. IT: Conceptualization, Writing–review and editing.

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.

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