INNOVATIONS IN SUSTAINABLE SEISMIC DESIGN

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The purpose of this article is to supplement recently developed concepts for Seismic Sustainability (SS) of new and existing buildings through practical detailing and descriptions of structural parts needed to achieve Post Earthquake Realignment and Repairs (PERR). Post-earthquake Global Stiffness Reduction (GSR) and Restoring Force Adjustment (RFA) methodologies have been addressed at some length. Attention has been focused on how complete buildings, including gravity framing, Earthquake Resisting Structures (ERS), supplementary devices and non-structural elements can be realigned after predicted earthquakes. SS is a concept that requires a thorough understanding of the mechanics of sequential failures and PERR. In PERR the resilience of the non-ERS system is as relevant as that of the ERS and the nature of the restoring forces are as important as those generated by the earthquake. Performance control (PC) is achieved through Design Led Analysis (DLA), which in turn is influenced by controlled behavior of purpose specific objectives. In the interim two novel methods of nonlinear displacement analyses of efficient Moment Frames (MF) have been presented. Several generic examples have been presented. The departure from damage to repairability based design requires a major shift in the current philosophical approaches to structural analysis and design. In SS the ability of the system to realign itself after a major earthquake is as important as its ability to resist the same earthquake without falling apart. The paper proposes a simple methodology with a paradigm shift that entails new detailing and performance requirements for the loading, unloading and re-centering stages of the structure. The need for proper detailing of self-centering systems was first discussed by Eatherton et al. (2014). The need for special detailing is equally important for SS. Recently, there has been a surge of interest in developing vibration dampers Basagiannis and Williams (2017) and replaceable fuses for ERS such as Slip Friction Joints, Shear Fuses (SFs) and moment connections, to cite a few Wang et al. (2017), Grigorian et al. (2018), etc. Although most of these implements have passed several tests of experiments and analysis, none can guaranty the functionality of the structure after an earthquake, unless the entire system has been designed to prevent physical collapse and re-center itself without major difficulties. Fortunately, almost all conventional structures can be upgraded to SS by the methods described in this paper. The post-earthquake response of buildings, including the gravity structure, nonstructural items, effects of residual stresses and strains, the nature of the restoring forces etc., are still not addressed in current codes of practice. Sustainability in this context implies the ability to prevent actual collapse, to overcome residual stresses and strains, the $P\delta$ effect during realignment, and to lend itself well to practical repairs. However, there is encouraging evidence that the engineering community has been looking forward to frameworks of resilient structural designs for earthquakes, Hajjar et al. (2013), Gebelein et al. (2017). However, as far as the authors can ascertain neither re-centering of earthquake damaged buildings nor full-scale experimentations involving rocking systems have been reported in the literature. The point of view here is that unless the entire building has been designed for PERR, no rational SS can take place. The current article aims to present a practical framework for SS. Both the theoretical as well as practical aspects of SS construction have been considered. For an in-depth discussion on idealized attributes for SS, the interested reader is referred to Grigorian (2017). In order to avoid tedious mathematics resort has been made to simple diagrammatic analysis that reduce the task of otherwise cumbersome computations to arithmetic combinations of idealized response curves. Moreover, the proposed design criteria rely mainly on simple modifications of conventional details and specifications. In order to emphasize the practical aspect of SS, mathematical formulations have been kept to a minimum. The validity and accuracy of all parametric examples have been verified by independent computer analysis.

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