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Assessment of Different Seismic Retrofit Systems of RC Buildings for Earthquake Risk Mitigation

by

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Abstract

Many existing Reinforced Concrete (RC) structures were designed and constructed at a time when design codes were insufficient according to current standards. This class of structures is at risk of damage when subjected to strong earthquake loading. Therefore, several seismic retrofit techniques have been investigated experimentally to increase the earthquake resistance and damage-control potential of pre-seismic code structures using different methods such as quasi-static and pseudo-dynamic testing. However, a limited number of studies have focused on investigating the overall seismic performance of retrofitted RC structures using shake table testing. The first task of this study assesses analytically and experimentally the effectiveness of selected retrofit techniques on enhancing the seismic performance of RC frames that represent the structural system of pre-code buildings. The selected seismic retrofit techniques are modeled and evaluated analytically using detailed fiber-based modeling approaches with the objective of delaying any possible failure modes. The shake table experimental program is then executed to assess the overall seismic performance of un-retrofitted and retrofitted specimens; each consists of two RC moment-resisting frames. While a control specimen is tested without retrofit, other specimens are retrofitted using CFRP wrapping and PBO-FRCM jacketing. The results obtained from the first phase of the study are utilized to arrive at verified numerical modeling approaches that are employed in the second phase to assess the seismic vulnerability of low- to medium-rise benchmark buildings with different retrofit techniques. In addition to CFRP and PBO-FRCM, the benchmark RC structures are retrofitted using steel BRB members with different arrangements and configurations. The considered arrangements include adding bracings at the middle or outer bays of external frames. Three configurations are also investigated, including split-X, inverted-V and double-K bracing systems. To develop fragility relationships with different retrofit approaches, the benchmark buildings are assessed probabilistically under two sets of input ground motions representing two seismic scenarios.

Based on the results of the experimental program, it is concluded that both CFRP wrapping and PBO-FRCM jacketing are effective in improving the seismic response of pre-code RC frames, especially the CFRP retrofit technique. The consistent results obtained from both the shake table testing and dynamic response simulations verify the adopted modeling approaches and enable deriving reliable fragility curves of the benchmark buildings before and after the retrofit. The double-K BRB system caused the highest reduction in limit state exceedance probabilities (LSEPs) compared with the other retrofit techniques, particularly under the effect of far-field earthquakes. The CFRP wrapping was also effective in reducing LSEPs for low-rise buildings under the effect of near-source events. For both considered seismic scenarios, the least reduction in LSEPs was observed for the PBO-FRCM jacketing as a result of the confirmed sudden loss of strength associated with debonding.

Keywords: Shake table, retrofit, seismic vulnerability, RC buildings, CFRP, FRCM, BRB.