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SEISMIC FRAGILITY ASSESSMENT OF DAMAGED RC FRAME UNDER CONSECUTIVE EXCITATIONS

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Common seismic design codes consider an intact structure subjected to an earthquake without including any initial damage. This might be acceptable based on the low probability of occurring earthquakes causing substantial damage during the lifetime of the structure, or based on the theory that there would be sufficient time to repair the building before the next earthquake. However, based on recent earthquake events particularly in Middle East (Kermanshah, 2017, Ahar-Varzeghan, 2012 and Van, 2011), there are substantial evidences that the issue of consecutive earthquakes is a real one for the structures in seismically active regions and should therefore be carefully studied and considered. These earthquakes may include aftershocks clustered near the main shock, or from nearby sources affecting similar regions.

In the past two decades, the issue of consecutive earthquakes has been the subject of several studies. Fragiacomo et al. (2004) conducted studies analyzing different types of structural systems. They indicated that damage in the systems subjected to repetitive earthquakes is significantly higher than those subjected to a single event. Hatzigeorgiou et al. (2013) showed that the deformation demands of the SDOF and MDOF systems are increased by repeated earthquakes. They quantified ductility demand spectra and behavior factors for structures subjected to multiple earthquakes and proposed an appropriate reduced behavior factor to take into account multiplicity effects. They also found that near-field and far-field earthquakes require different ductility demands. Abdelnaby concluded that stiffness and strength degradation significantly affects the final deformations of RC frames subjected to multiple earthquakes.

According to some rigorous researches on the nature and effects of near field (NF) ground motions, the seismic ground motions recorded within the near-fault region of an earthquake are qualitatively quite different from the usual far field (FF) seismic ground motions. Normally in a seismic region, the locations of the main-shock and its aftershocks are not necessarily the same. Yue et al. investigated two cases of seismic sequences, a FF main-shock followed by a FF aftershock and a FF main-shock followed by NF aftershock, for one steel frame structure to evaluate the collapse fragility. They conclude that although the mean structural collapse capacity for near-fault aftershocks is smaller than that for far-fault aftershocks, the collapse capacity appears to be more sensitive to FF aftershocks when the building experiences severe damage from the main-shock. Garcia and Mariquez (2010) studied steel frames under as-recorded FF and NF multiple earthquakes. They concluded that under NF earthquakes the interstory drift ratio is larger than when under FF earthquakes.

This paper aims to investigate the effects of consecutive near-field and far-field earthquakes on a four-story RC frame with hysteretic stiffness and strength degrading characteristics to the different orders of consecutive near-field and far-field earthquakes. 22 far-field and 28 near-field records as suggested by FEMA P695, are selected. Four main consecutive scenarios (FFFF, FFNF, NFFF, NFNF) are defined. The performance evaluation is carried out for various first shock damage levels and second shock performance levels.

Figure 1 presents fragilities under FFFF and FFNF where the first shock damage levels are different. The figure includes three performance levels under the second shock for each scenario. Comparing two cases in this figure illustrates the effects of the second shock type (far-field or near-field) on the probability of exceedance for 4-story RC

framed system under consecutive earthquakes. According to the results, increasing initial damage levels cause significant increase in second shock performance probability of exceedance.

It is concluded that consecutive near field seismic excitations may result in more lateral transient and permanent deformations as compared with far field ground motions. Considering the effects of residual drift on the system's response to consecutive earthquakes, it is also shown that there are differences in the probability of performance exceedance to consecutive earthquakes according to the record type (FF or NF).

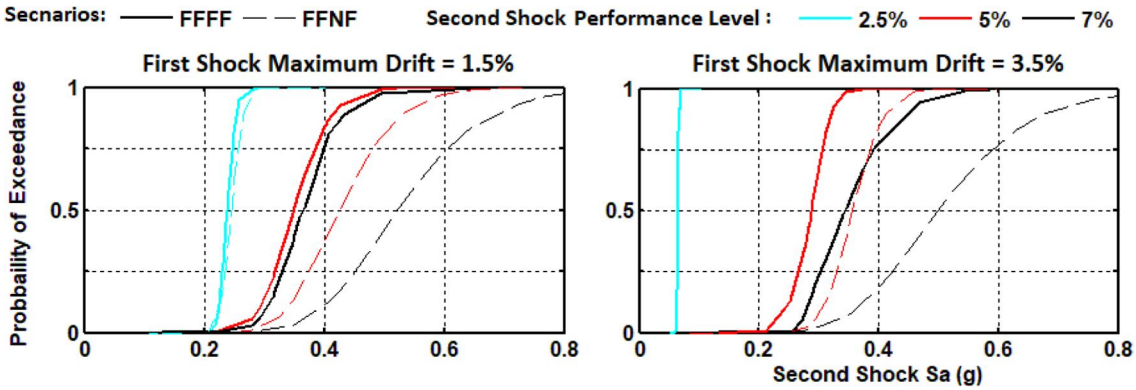

Figure 1. Fragilities of consective scenarios with the same first shock, considering three different second shock performance levels under two initial damage levels (1.5% and 3.5%).

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