THE EFFECTS OF NEAR-FIELD AND FAR-FIELD MULTIPLE EARTHQUAKES ON SINGLE STORY RC FRAMES

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Uncertainty inherently exists in every aspect of seismic design procedure of structures from the seismic source to structural characteristics and numerical modelling. Along with the development of computational tools, probabilistic extension has facilitated the way we deal with these uncertainties and has provided new opportunities for their explicit consideration. Most of the methods associated with the application of probabilistic concepts are demanding in terms of computational time and efforts. There are also some subsidiary methods that can reduce computing demands while maintaining their powerful probabilistic framework.

Most of the structures situated in seismic regions experience several earthquakes during their lifetime. Multiplicity of these earthquakes becomes important when they reduce the seismic capacity by causing residual deformations in the structure. Quantification of this capacity reduction in combination with characterization of two possible earthquakes is the key factor in assessing the likely effects of multiple earthquakes on the design of the structures. Due to considerable variability and uncertainties involved in this phenomenon the probabilistic approach would be the most advantageous one.

The majority of research studies in earthquake engineering field consider the effects of a separate earthquake on an intact structure i.e. without any initial seismic capacity deterioration. This consideration might have been justified based on the low probability of occurring two ground motions of significant effects in the lifetime of the structure, or based on the assumption that there would be sufficient time to assess and repair the structure after the first event. However, based on recent experiences (Chile (2010), Christchurch (2010, 2011), Tohoku (2011), Van (2011), Ahar-Varzeghan (2012) and Greece (2014)), there are sufficient evidences that the issue of a structure to be subjected to two or even more consecutive earthquakes is real and therefore requires adequate attention. These earthquakes may be considered as from the same seismic source commonly known as foreshocks, main shocks and aftershocks, or from nearby sources affecting similar regions.

In the past few years, some research studies have been carried out by Luco and co-workers investigating the effects of multiple earthquakes, mainly focusing on structures' performance levels. Luco et al. (2011, 2012) used probabilistic approach to develop fragility curves for estimating the probability of exceeding the collapse performance level under aftershock. Figure 1 depicts the extent of increase in the probability of collapse due to the single seismic event excitation as compared to single seismic event.

It is now well known that the seismic ground motions recorded within the near-fault region of an earthquake are qualitatively quite different from the usual far fault seismic ground motions. Near field seismic ground motions are frequently characterized by intense velocity and displacement pulses of relatively long period that are clearly distinguished from typical far field ground motions. Although, there has been some notable studies on the nature and effects of near field ground motions, no substantial research has been carried out to study the effects of multiple ground motions on the structures while taking into account the effect of proximity to earthquake source. This paper aims to investigate the effects of multiple near-field and far-field earthquakes on single story RC frames modeled as a SDOF system with various hysteretic stiffness and strength degrading characteristics. In order to evaluate frame's behavior under these seismic situations, the structures are considered to have a spectrum of various dynamic properties and hysteresis behavior. The structures are analyzed using nonlinear incremental dynamic method (Vamvatsikos and Cornell, 2002) and fragility curves, indicating probability of structural response exceeding different performance levels, are evaluated. Maximum transient and permanent drift ratios are used as main performance indicators.

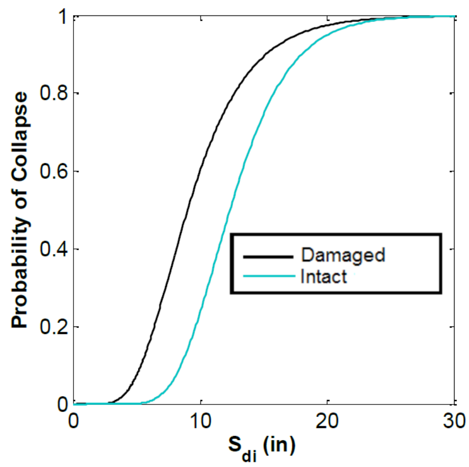

Figure 1. Fragility curve comparison of intact and damaged structures (Luco et al., 2012)

The main innovation of this study is to shed light on the effects of sequential near field and far field ground motions, in probabilistic term, on the performance of the seismic resistant structures simplified as single degree of freedom systems. It is concluded that multiple near field seismic excitations may result in more lateral transient and permanent deformations as compared with far field ground motions. Furthermore, probability of structural response exceeding the intended performance level is shown to be higher, to some extent, in the case of near field ground motions. It is also shown that the extent of these differences depends on the structural dynamic characteristics which are sensitive to ground motion frequency contents. This suggests that multiple near field and far field earthquakes would require different seismic considerations within the design procedure. Recommendations are provided on the threshold of seismic excitations as a seismic hazard level to be considered and the expansion of the probabilistic method for MDOF structures.

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