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THE COLLAPSE ASSESSMENT OF THE LOW-RISE ASYMMETRIC DUCTILE RC FRAME BUILDINGS WITH A LESS-SENSITIVE INTENSITY MEASURE TO THE SPECTRAL SHAPE EFFECTS

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Nonlinear dynamic analysis is frequently applied for the earthquake-induced collapse estimation. Thus, it is important to understand the ground motion properties that are more effective in a building collapse. The ground motion intensity is a well-known property that is used in a dynamic analysis. It should reveal the impact of earthquake record characteristics on a structure. A proper intensity measure is sufficient and efficient enough when it results in small variability of demand and reduces the number of dynamic analysis assessing structural performance. Spectral acceleration at the fundamental period of a structure, Sa (T_1), is a very common intensity measure used in the collapse assessment of structural systems. However, it is not the most efficient and sufficient IM for most applications (Luco & Cornell, 2007). Therefore, researchers have introduced some new measures (Mousavi et al., 2011). For instance, Baker and Cornell (2005) indicated that the acceleration spectrum of rare earthquakes was much different from the code design spectrum. They introduced a vector-valued IM based on the spectral shape parameter named Epsilon (ε). Later, several studies implied its importance on the structural collapse capacity (Haselton & Baker, 2006). A study by Haselton and Baker (2006) also showed that the spectral shape effect on the variance of collapse capacity of the single-degree-of-freedom systems was changing while the fundamental period of the system was varying. When a ductile building subjects to strong ground motions, it behaves nonlinearly and the structural period elongates. This study investigates if the spectral acceleration at the extended period is a more proper IM than the common intensity measure, i.e., S_a (T_1) to utilize for assessing the collapse of the asymmetric reinforced concrete special-moment-frame buildings.

The reinforced concrete special-moment-frame (RC-SMF) buildings are the example buildings. The buildings are designed using SAP2000 based on ACI 318-05 and Iranian seismic codes. The code fundamental period (T_{code}) and the associated design base shear coefficient (C_y) of the 5-story buildings are 0.6 (sec.) and 0.078, respectively. To examine the example buildings' collapse, OpenSees is adopted for modeling and analysis. In the building models, structural elements (i.e., beams and columns) are idealized using an elastic beam element with nonlinear rotational springs at each end. The spring model developed by Ibarra et al., (2005) is capable of capturing the monotonic and cyclic deterioration modes. The models' irregularity is simply 10 and 20% mass eccentricities induced in the one-way of the plan. However, the effects of all other important parameters keep constant in each asymmetric building.

In extreme ground motions, a ductile building behaves nonlinearly. Therefore, the effective-mode period of the building increases due to nonlinear effects. It is investigated if the spectral acceleration using a lengthened period ($T_{eff.}$) may better explain the ground motion effect on the asymmetric building models' response near collapse than the common intensity measure at the model fundamental period, i.e., S_a (T_1). The secondary goal of the study is to examine the sensitivity of results to the spectral shape effects. Hence, the asymmetric models are subjected to a record set selected without regard to the spectral shape. However, the building models' collapse capacity is also evaluated considering those effects. Haselton and Deierlein (2006) implemented a linear regression method to investigate the effect of spectral shape parameter that is Epsilon on the collapse safety of 65 reinforced concrete frames. Here, it is assumed that the example buildings locate in a high seismic region where the expected Epsilon value is typically ranging from 1.0 to 2.0, and is 2.0 in this study. Additionally, the linear regression method is used to take into account the ε effect on the collapse capacity of the asymmetric models. Incremental dynamic analysis (IDA) is performed to estimate the collapse capacity of the models, and by 44 seismic records. For each building model, the collapse analysis is repeated using S_a ($T_{eff.}$) as the intensity measure where $T_{eff.}$ is related to a period range including the model fundamental period. The lower and the upper bond of that period range are 0.6 that is T_{code} and 2.0 second, respectively. The fundamental period of the building models (i.e., T_1) is ranging 0.8 to 0.9 second.

According to the collapse analysis, there is a period range in which the spectral shape of a record fewer affects the collapse assessment results. It is called the optimal period range (OPR) hereafter. The OPR is chosen based on two criteria. First, if the effective-mode period of a building model (i.e., T_{eff}) is selected within the so-called range, its collapse capacity will be less sensitive to the record selection method. In other words, the collapse capacity of the building model with and without regarding the Epsilon effect closes together in that period range. Second, values of record-to-record variability of the collapse capacity will be less than 0.35 at the optimal period range. For various building types as stated in FEMA P-695, it is fairly consistent that values of record-to-record variability to range from 0.35 to 0.45. The OPR is the shortest period range where the variance of collapse capacity catches the value of 0.35. According to the criteria, the optimum period values are ranging from 1.0 to 1.7 second, and in other words, $1.2T_1$ to $2T_1$. Without regard to the asymmetry, the minimum variance of collapse capacity is obtained within the optimal range of periods. For instance, Figure 3 shows the variance of collapse capacity (i.e., $\sigma_{Ln(Sa\ collapse)}$ on the vertical axis) and the OPR for the 20% mass eccentric model. Thus, the spectral acceleration is a sufficient intensity measure if the effective period of building models is selected through the optimum range. It is also noteworthy that the red dot on the intersection is the point where the collapse variability has the same value for both results with and without considering the spectral shape effects.

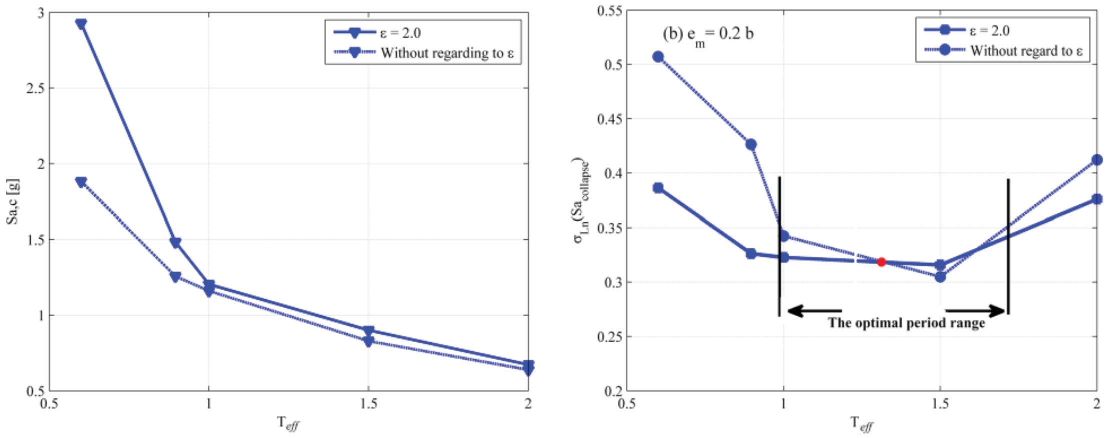

Figure 1. The optimal period range for 20% mass eccentric building model.

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