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INVESTIGATING THE POUNDING EFFECTS ON THE SEISMIC COLLAPSE CAPACITY OF ADJACENT RC AND STEEL SMRFS

Farzin KAZEMI
M.Sc. in Earthquake Engineering, Imam Khomeini International University, Qazvin, Iran
farzin.kazemi@edu.ikiu.ac.ir

Mohammad Reza AZADI KAKAVAND
Ph.D. Candidate, University of Innsbruck, Innsbruck, Austria
mohammad.azadi-kakavand@uibk.ac.at

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Several numerical studies have been performed to investigate the pounding phenomenon for reducing structural damages during severe earthquakes. This phenomenon occurs due to insufficient clear distance between adjacent buildings, the difference between fundamental periods, mass and stiffness. Many studies focused on the numerical modeling of the impact force using contact elements such as linear elastic, linear viscoelastic, modified linear viscoelastic, nonlinear viscoelastic and modified Hertzdamp model. While, Khatiwada et al. (2013) showed that the linear viscoelastic contact model showed better performance and was recommended for pounding simulations among the nonlinear viscoelastic, modified linear viscoelastic, and modified Hertzdamp models. Therefore, in this study, to model the pounding phenomenon, the linear viscoelastic contact model was developed in OpenSees software. For all pounding Special Moment Resisting Frames (SMRFs), the impact damping coefficient, C_{imp}, and the impact stiffness, K_{imp}, were obtained from studies performed by Kazemi et al. (2018a) and Mohebi et al. (2018).

In this research, the 6- and 9-Story steel SMRFs designed by Kitayama and Constantinou (2016) were assumed. These structures were assumed to be located in high seismic regions of California at latitude 37.8814°N and longitude 122.08°W, with soil class D and seismic design parameters of SD_S=1.25g and SD_1=0.6g. The response modification factor of R=8, the deflection amplification factor of Cd=5.5 and the system over-strength factor of Ω=3 were selected for SMRFs. The floor dead and live loads of 3.35 kN/m^2 and 1.68 kN/m^2 and the roof dead and live loads of 1.68 kN/m^2 and 0.96 kN/m^2 were applied to the structures, respectively. These structures were considered as a taller structure in adjacent of the 2- and 4-Story RC SMRFs, which were designed by Haselton and Deierlein (2007) (design ID of 2- and 4-Story RC SMRFs are 2064 and 1003, respectively). Structures were considered in Northern Los Angeles, with soil class D and seismic design parameters of SD_S=1.5g and SD_1=0.9g. It was mentioned that the P-Delta effect plays a crucial role in the sideway collapse of pounding structures (Kazemi et al., 2018a; Mohebi et al. 2018). Therefore, to consider three-dimensional effects, all columns except those in the SMRFs are assumed as gravity columns and were modeled as leaning column. Moreover, to model beams, a nonlinear rotational spring at both ends of each element, which the Modified Ibarra–Krawinkler bilinear-hysteretic model was applied in zero-length elements, was used. In addition, to model columns, the Steel02 material and NonlinearBeamColumn element in OpenSees were employed (Kazemi et al., 2018b and 2019). To consider the effects of increasing the clear distance, three clear distance of 0.0, 0.5D and 1.0D, where D is the minimum clear distance prescribed by the ASCE07-10, were assumed. To assess the values of seismic collapse capacity of both structures in one model, an algorithm was developed to automatically remove the collapsed structure during Incremental Dynamic Analyses (IDAs). IDAs performed assuming 28 near-field earthquakes having pulse subset and 28 near-field earthquakes having no-pulse subset presented in FEMA P695. This approach was also employed in prior research studies to assess the onset of shear and axial failure in RC columns (Azadi and KhanMohammadi, 2018, Azadi and Allahvirdizadeh, 2019).

Figure 1 shows the IDA curves of the 4-Story RC and the 9-Story steel SMRFs without pounding in grey color. In addition, the median collapse capacities of the SMRFs in alone and pounding condition given a clear distance of 1.0D are presented by blue and red color, respectively. The flat part of each IDA curves shows the $S_a(T_1)$, which terms the seismic collapse capacity of the structure. For example, the median collapse capacity of 4-Story RC and the 9-Story steel SMRFs without any adjacent structure are 1.048 and 0.892, respectively. According to this figure, considering the pounding phenomenon increases the median collapse capacity of the 4-Story RC SMRF by 28.61%. On the other hand, the median collapse capacity of 9-Story steel SMRF increases by 5.9%. In addition, the results show that in the pounding condition, the median collapse capacity of the pounding RC and steel SMRFs increases by increasing the clear distance. In other words, when the clear distance increases from 0.0 to 1.0D, the median collapse capacity of the 4-Story RC SMRF increases from 1.228 to 1.468, respectively. Moreover, the pounding phenomenon can influence the probability of collapse. Therefore, it was recommended that the adjacent structures in real condition should be considered in modelling especially for retrofitting purpose.

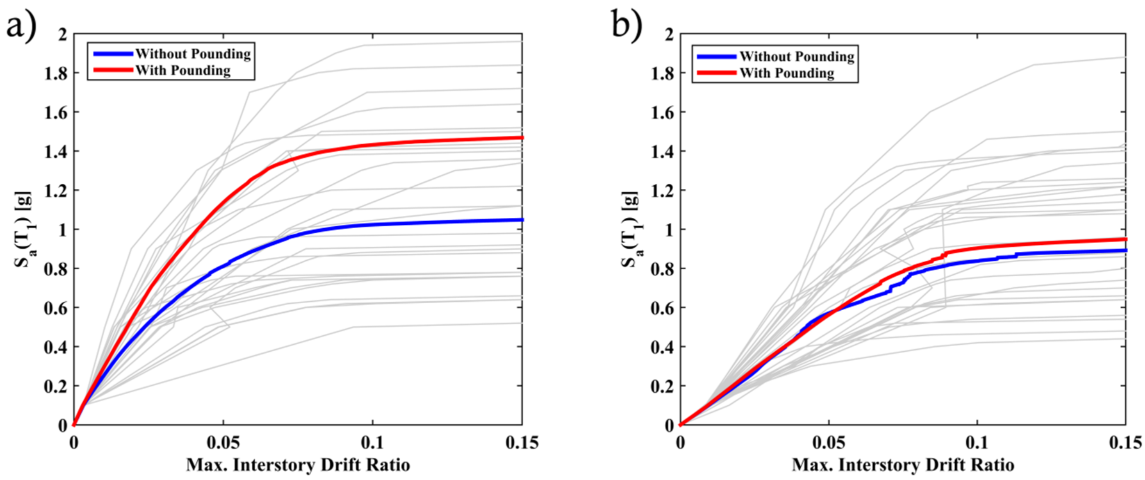

Figure 1. IDA curves of the 4-Story RC SMRF, section a, pounding with the 9-Story steel SMRF, section b, with clear distance of 1.0D subjected to 28 near-field earthquakes having pulse subset.

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