MAINSHOCK INTENSITY EFFECTS ON SEISMIC FRAGILITY OF RC MRFS UNDER AFTERSHOCKS

Afshin KALANTARI
Associate Professor, IIEES, Tehran, Iran
a.kalantari@iiees.ac.ir

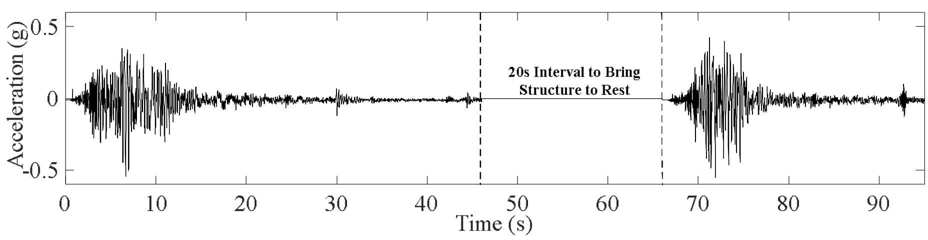
Hamed ROOHBAKHSH
Ph.D. Candidate, IIEES, Tehran, Iran
h.roohbakhsh@iiees.ac.ir

Keywords: RC Building, Seismic Sequence, Seismic Vulnerability, Nonlinear Analysis

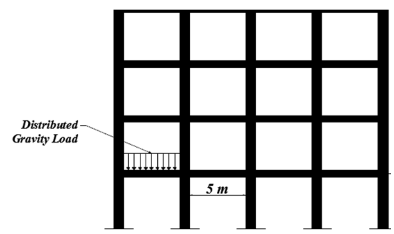
Several researchers including Amadio et al. (2003), Luco et al. (2004), Rinaldin et al. (2017) and Abdelnaby (2018) have investigated the aftershock effects on the seismic vulnerability of buildings.

This study, calculates the seismic fragility of RC Moment Resisting Frames (MRFs), designed based on the last three editions of Iranian code of practice for seismic resistant design (Standard No. 2800 (STD-2800)) under a second event, on the condition of different mainshock scenarios. To this end, three models of 4 storey MRFs are considered. The frame models were designed and detailed based on the last three editions of the STD-2800 and referred as Frame 2, Frame 3 and Frame 4, respectively. To calculate the seismic fragility, twenty mainshock-aftershock sequences were employed. OpenSees finite element software was used to perform incremental nonlinear dynamic analysis (McKenna et al., 2011). A proper material property was used in the model in order to capture the residual displacement and damage effects after the first seismic event. Maximum interstory drift values were employed as a damage index, to capture the performance of the models in mainshock-aftershock sequences. Three main-shock scenarios were employed in the study. Maximum interstory drift for the collapse level was selected from the Iranian instructions for seismic rehabilitation of existing buildings (PBO-Publication No. 360, 2007).

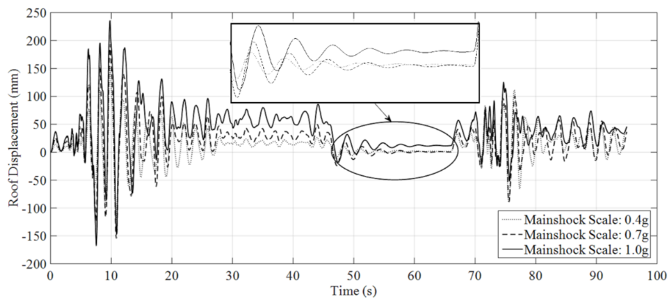
Procedure of the calculations including preparation of seismic sequence, frame model and time history results for a ground motion record are shown in Figure 1.



a) A seismic sequence applied to model



b) Four storey frame modelled in OpenSEEs



c) Time history analysis of a 4 storey frame subjected to a sequence of ground motions

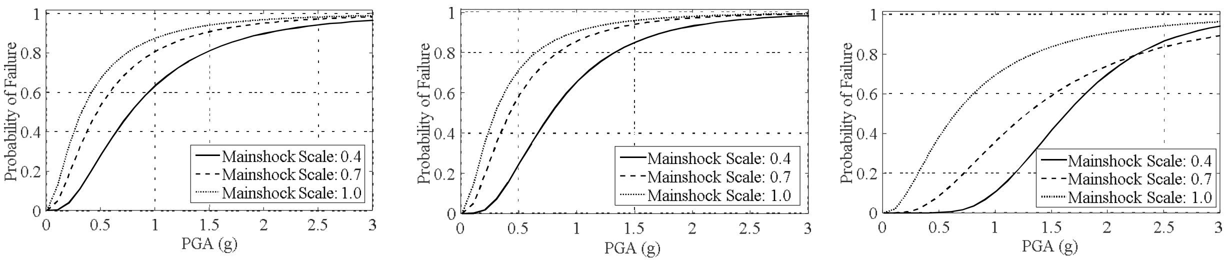
Figure 1. Modelling and analysis procedure.

Table 1 shows how the mainshock event could increase the vulnerability of the Frame 2 under aftershocks. It can be observed that in a frame experiencing a mainshock with a PGA of 0.4g, aftershocks with PGA values of 1.11g and 2.18g have caused the frame to proceed to the life safety and collapse prevention limit states, respectively. Meanwhile, if the mainshock intensity climbs to 0.7g, the similar damage states are met in considerably lower aftershock PGA values of 0.62g and 1.77g, respectively.

Table 1. Aftershock PGA for Frame 2 in two performance levels.

Mainshock intensity level PGA(g)	**Corresponding aftershock PGA(g)**	
	Life safety	Collapse prevention
0.4	1.11	2.18
0.7	0.62	1.77
1.0	0.22	1.65

Results of aftershock collapse fragilities are useful to examine the collapse capacity of RC structures with partial damage due to mainshock excitations. As shown in Figure 2, the results of the study indicate how the probability of collapse of the studied RC moment frames increases as a result of seismic sequence effects. It is observed that for example in Frame 4, for mainshock PGA values of 0.4 and 1.0g, the aftershock fragility values are 0.1 and 0.65, respectively when subjected to aftershock of PGA=1.0g. The results also indicate the enhancement of seismic performance of RC frames designed by the more recent editions of the Iranian code of practice for seismic resistant design.



(a) Frame 2 (b) Frame 3 (c) Frame 4

Figure 2. Aftershock collapse fragility curves.

ACKNOWLEDGEMENTS

We thank the Iranian National Science Foundation for partially funding this project as the grant number 96005525, along with the IIEES research project number 696.

REFERENCES

Abdelnaby, A.E. (2018). Fragility curves for RC frames subjected to Tohoku mainshock-aftershocks sequences. *Journal of Earthquake Engineering*, *22*(5), 902-920.

Amadio, C., Fragiacomo, M., and Rajgelj, S. (2003). The effects of repeated earthquake ground motions on the non-linear response of SDOF systems. *Earthquake Engineering & Structural Dynamics*, *32*(2), 291-308.

Luco, N., Bazzurro, P., and Cornell, C.A. (2004). Dynamic versus static computation of the residual capacity of a mainshock-damaged building to withstand an aftershock. *13th World Conference on Earthquake Engineering*.

McKenna, F., Mazzoni, S., and Fenves, G.L. (2011). Open System for Earthquake Engineering Simulation (OpenSees) Software Version 2.2.0. University of California, Berkeley, CA. Available from http://opensees.berkeley.edu.

Management and Planning Organization of Iran, Publication No. 360 (2007). *Specification of Seismic Evaluation and Retrofit of Buildings*.

Rinaldin, G., Amadio, C., and Fragiacomo, M. (2017). Effects of seismic sequences on structures with hysteretic or damped dissipative behavior. *Soil Dynamics and Earthquake Engineering*, *97*, 205-215.