8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

ENERGY ABSORPTION AND INELASTICITY DISTRIBUTION MECHANISMS IN STEEL MOMENT FRAMES AFFECTED BY MAINSHOCK-AFTERSHOCK SEQUENCES

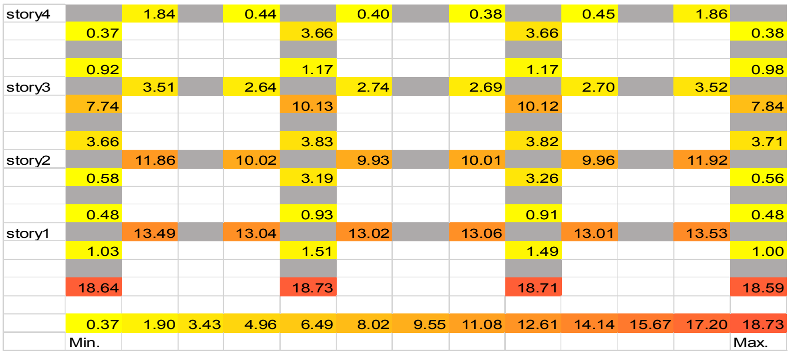
Mohammadmehdi TORFEHNEJAD
Ph.D. Candidate at Civil Engineering Department, Eastern Mediterranean University, Turkey
mehdi.torfehnejad@students.emu.edu.tr
Serhan SENSOY
Chair of Civil Engineering Department, Eastern Mediterranean University, Turkey
serhan.sensoy@emu.edu.tr

Keywords: Mainshock-Aftershock Effect, Hysteretic Energy, Plasticity Distribution, Steel Moment Frames

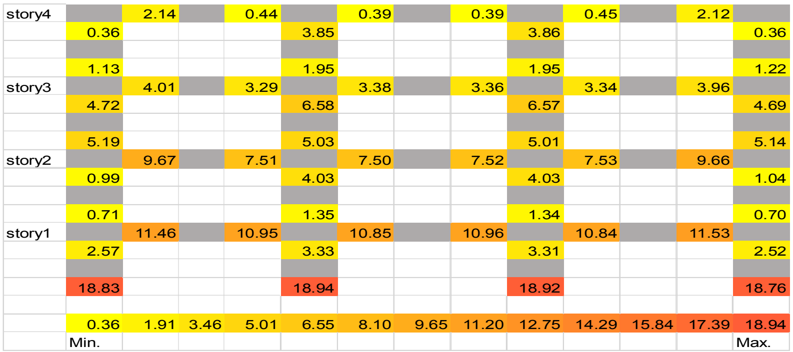
Many structures sustain damage during a mainshock earthquake but undergo severe damage due to the following aftershocks. The effect of mainshock-aftershock sequence on seismic collapse capacity of structures needs, therefore, be evaluated in addition to the mainshock-only being currently addressed by design standards. Seismic performance of structural systems is affected, on the other hand, by the mechanism through which earthquake-induced energy is dissipated. In Special Steel Moment Frame (SSMF) systems being the subject of this study, such energy absorption is provided by ductile inelastic behavior of frame members. Thus, plasticity distribution and the subsequent contribution of members in damping seismic input energy are of primary importance in assessing collapse behavior of these systems under mainshock-aftershock sequences.

Identifying the mechanisms that lead to lateral collapse of structures under seismic events has been subject of many studies (e.g. An et al., 1997; D'Ayala & Speranza, 2003; Kiyono & Kalantari, 2004; Yi, et al., 2007). The aim of such studies is to provide insight into how the elastic and inelastic demands of structures have to be estimated for effective mitigation of seismic risks. The methodology employed by the majority of these studies for evaluating collapse mechanism has focused on distribution of lateral drifts between various stories of a frame. However, the main cause of story drift accumulation triggering the collapse is plasticity localization. Therefore, studying the distribution of inelastic (ductility) demand throughout a building can be more informative than evaluation of story drifts distribution and is regarded in the current study.

On the other hand, in structures without added energy dissipative devices (dampers), the structural members are responsible for damping input energies by undergoing cycles of inelastic deformations. Therefore, plastic deformations can be considered as a means for dissipating the induced seimic energy. Thus, a close correlation there appears between the experienced plastic deformations and the role of various members in absorbing seismic energy. These correlains are addressed in current study by looking to the collapse mechanism from two various perspectives. One is distribution of plasticity throughout the sructure and the other is contribution of various members in absorbing the total hysteretic energy. Both these distributions are avergaed at the collapse states obtained for a suit of 32 as-recorded mainshock-aftershock sequences. For this purpose, four SSMFs with 4 to 20 stories previously designed by NIST (2010) are selected. Each structure is then numerically modelled and verified in OpenSees (Mazzoni et al., 2004) and is subjected to incremental dynamic analysis (IDA) (Vamvatsikos & Cornell, 2002). In IDAs, the mainshocks intensity level is kept constant while the aftershock is being increasingly scaled. The IDAs are then repeated by considering various mainshock scales following the methodology used by previous researchers (e.g. Li et al., 2014). In previous studies, the mainshcock scale was determined in accordance with the maximum inter-story drift ratio (MIDR) induced by it. In a previous study by the authors, it was found that MID parameter is not a good representative of the damage level induced by mainshock. Thus, as an improvement to the methodology, maximum residual story drift (MRSD) is considered and set equal to different values to reflect the variability in mainshock intensity or damage level. An example of results obtained by these analyses is presented in Figure 1. In this figure, the average maximum ductility demand (MDD) values obtained at the collapse state are summarized in a contour form (colours reflect greateness of values). For evaluating the effect of mainshock-aftershock sequence, the aftershock-only results are compared against the sequence excitation in which mainshock is scaled to induce a MRSD=0.04 value. As this comparison indicates, similar overall patterns are obtained for distribution of MDDs in the two cases and minor differences there appear between counterpart MDD values. Further interpretation of these results is beyond the scope of this abstract and will be provided later.



(a) Under mainshock-aftershock sequence with mainshock scaled to MRSD=0.04 level



(b) Under aftershock excitation only

Figure 1. MDD contour obtained at the collapse state for 4-story SSMF subjected to various excitations.

REFERENCES

An, X., Shawky, A.A., and Maekawa, K. (1997). The collapse mechanism of a subway station during the Great Hanshin earthquake. *Cement and Concrete Composites, 19*(3), 241-257.

D'Ayala, D. and Speranza, E. (2003). Definition of collapse mechanisms and seismic vulnerability of historic masonry buildings. *Earthquake Spectra, 19*(3), 479-509.

Kiyono, J. and Kalantari, A. (2004). Collapse mechanism of adobe and masonry structures during the 2003 Iran Bam earthquake. *Bull. Earthq. Res. Inst. Univ. Tokyo, 79*(157), 161.

Li, Y., Song, R., and Van De Lindt, J.W. (2014). Collapse fragility of steel structures subjected to earthquake mainshock-aftershock sequences. *Journal of Structural Engineering, 140*(12), 04014095.

Mazzoni, S., McKenna, F., Scott, M.H., and Fenves, G.L. (2004). *OpenSees USERS MANual*: PEER Center, University of California, Berkeley.

NIST (2010). *Evaluation of the FEMA P-695 Methodology for Quantification of Building Seismic Performance Factors.* National Institute of Standards and Technology, NIST GCR 10-917-8.

Vamvatsikos, D. and Cornell, C.A. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics, 31*(3), 491-514.

Yi, W., He, Q., and Xiao, Y. (2007). Collapse performance of RC frame structure. *Jianzhu Jiegou Xuebao/Journal of Building Structures, 28*(5), 104-109.