EVALUATION OF ESSENTIAL STRUCTURES PERFORMANCE UNDER MAINSHOCK-AFTERSHOCKS SEQUENCE-TYPE GROUND MOTIONS

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After occurrence of the strong mainshock a series of aftershocks often occurred follow by the mainshock, with different intervals of time. Some structures such as hospitals and relief centers under the strong ground motion must have an appropriate performance subject to the probable aftershocks that follow the main event. These structures should have non-stop services after occurrence of the aftershocks. However most of seismic codes, for design purpose, just use a single ground motion "design earthquake" and they don't have any attention to aftershocks (Ruiz-García, 2012). Base on this gap in design of essential structures, the performance of these structures needs to be evaluated under mainshock-aftershock sequence-type ground motions. The main aim of this study is to evaluate performance of two hospital reinforced concrete (RC) frames under repeated earthquakes. In this study assessment of inelastic response of frames under sequence-type ground motions was compared to single events.

To determine parameters such as roof residual displacement (RRD) demands and Park–Ang Damage Index (DI) (Park et al., 1985) of structure, the non-linear structural analysis software IDARC v6.0 was utilized (Reinhorn et al., 2004). The results indicate that in order of better performance of these frames, they also should be re-evaluated under the effect of repeated earthquakes.

A 6-story RC frame of the hospital was examined under sequential earthquakes. In this study as a reference (Ruiz-García et al., 2014) proposed, ratios of peak ground motion acceleration of aftershock (PGAas) to peak ground motion acceleration of mainshock (PGAms) (PGAas/PGAms= 0.35, 0.70, 1.0) and real sequences were considered. Table 1 shows the details of seismic sequences at El Centro station during the 1979 Imperial Valley earthquakes (PEER, 2014). A comparison between spectral acceleration computed from the mainshock and real mainshock-aftershock ground motion recorded during the 1979 Imperial Valley earthquakes is shown in Figure 1. It can be observed that the main shock and mainshock-aftershock ground motion have different frequency contents.

Table 1. Seismic sequence selected from the Pacific Earthquake Engineering (PEER) database

No.	Earthquake name	Station	Date	Time	PGA (cm/s²)	Type
1	Imperial Valley	5115 El Centro	1979/10/15	23:16	0.291g	Main shock
2	Imperial Valley	5115 El Centro	1979/10/15	23:19	0.150g	Aftershock

Displacement time-history response and the RRDs of a 6-story RC frame under Imperyal Valley seismic sequences with respect to different PGAas of the mainshock-aftershock ground for three ratios of (PGAas/PGAms= 0.35, 0.70, 1.0) and real mainshock-aftershock sequences (as-recorded) are evaluated. As is clear, residual roof displacements under sequences (RRDseq) with severe intensity of PGAas (PGAas/PGAms= 0.70, 1.0) compared to residual roof displacements under mainshock (RRDms) are significant. However, RRDseq of the aftershocks with low intensity of PGAas (PGAas/PGAms= 0.35) is negligible.

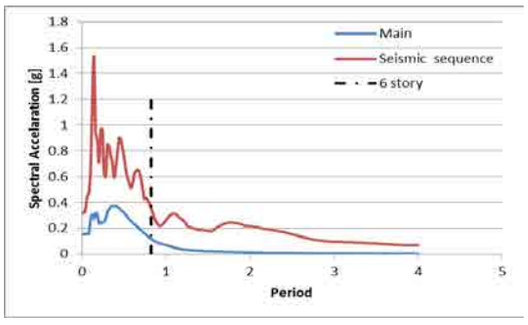

Figure 1. A comparison between spectral acceleration computed from the mainshock and as-recorded sequences

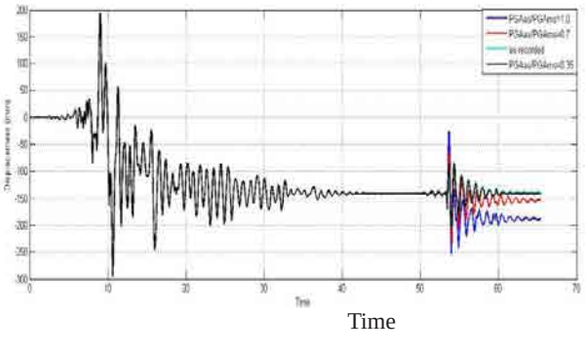

Figure 2. Displacement time-history response and RRD of a 6-story RC frame with different PGAas/PGAms ratios

In Table 2, the RRDs of a 6-story RC frame under Imperial Valley seismic sequences with respect to different PGAas of the mainshock-aftershock ground motions for any ratios of PGAas/PGAms are evaluated. As is clear, RRDseq with severe aftershocks increase up to 30% of the occurrence of just mainshock.

Table 2. Comparison of RRDseq with different ratios of PGAas/PGAms respect to RRDms

No.	Seismic sequences	RRD seq (mm)	RRDms (mm)	RRDseq/RRDms(%)
1	Real sequences	-.14170E+03	-.14407E+03	0.98
2	PGAas/PGAms=0.35	-.14003E+03	-.14407E+03	0.97
3	PGAas/PGAms=0.70	-.15469E+03	-.14407E+03	10
4	PGAas/PGAms=1.0	-.18770E+03	-.14407E+03	30

A general structural damage based on Park-Ang damage index (DI) of a 6-story RC frame under Imperial Valley seismic sequences with respect to different PGAas of the mainshock-aftershock ground motions for every ratios of PGAas/PGAms are evaluated is shown in Table 3. As is obvious, the DI of the frame under sequences (DIseq) with severe aftershocks increase up to 17% of the occurrence of just mainshock, while damage of the aftershocks with low intensity of PGAas is negligible. Refer to the scope of damage to structures on Park-Ang damage index, as it can be seen, progress of structural damage of frame under seismic sequences, even though happened severe aftershocks, is not remarkable, compared to the mainshock, and structural damage of frame under seismic sequences remain in same scope comparing to the occurrence of just mainshock.

Table 3. Comparison DIseq with different ratios of PGAas/PGAms respect to DIms

No.	Seismic sequences	DIseq	DIms	DIseq/Dims (%)
1	Real sequences	0.124	0.122	2
2	PGAas/PGAms=0.35	0.122	0.122	0
3	PGAas/PGAms=0.70	0.130	0.122	7
4	PGAas/PGAms=1.0	0.143	0.122	17

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