Numerical parametric study of SDOF self-centering systems under MCEER Ground Motions

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ABSTRACT

A comprehensive numerical parametric study is conducted to determine the seismic response of single-degree-of-freedom (SDOF) systems with the self-centering, hysteretic structural behavior. An ensemble of 25 simulated MCEER Ground Motions having a probability of exceedence of 10% in 50 years, in Northridge, California, was used in this parametric study. The seismic responses of the self-centering hysteretic SDOF systems were compared with the responses of similar bilinear elasto-plastic hysteretic SDOF systems. It was shown that a self-centering hysteretic SDOF system with different parameters can be found to get the similar or better responses of an elasto-plastic hysteretic SDOF system in terms of displacement demand or acceleration demand or combined demand and without leading to any residual drift from the seismic event.

BACKGROUND

After a moderately strong earthquake, the cost associated with the loss of business operation, damage to structural and non-structural components can be significant to modern society.

With current design approaches, most structural systems are designed to respond beyond the elastic limit and eventually to develop a mechanism involving ductile inelastic response in specific regions of the structural system, which is called Elasto-Plastic structures (EPS) shown in Fig. 1.

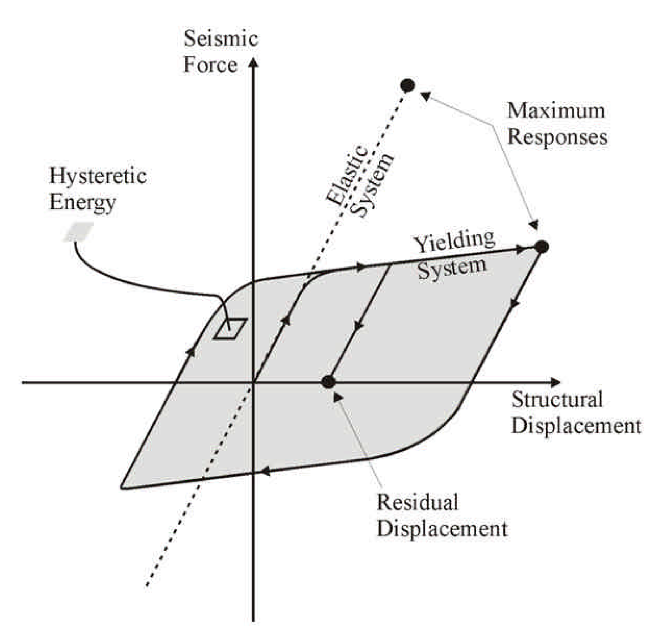

Figure 1. Response of Elasto-Plastic Structures

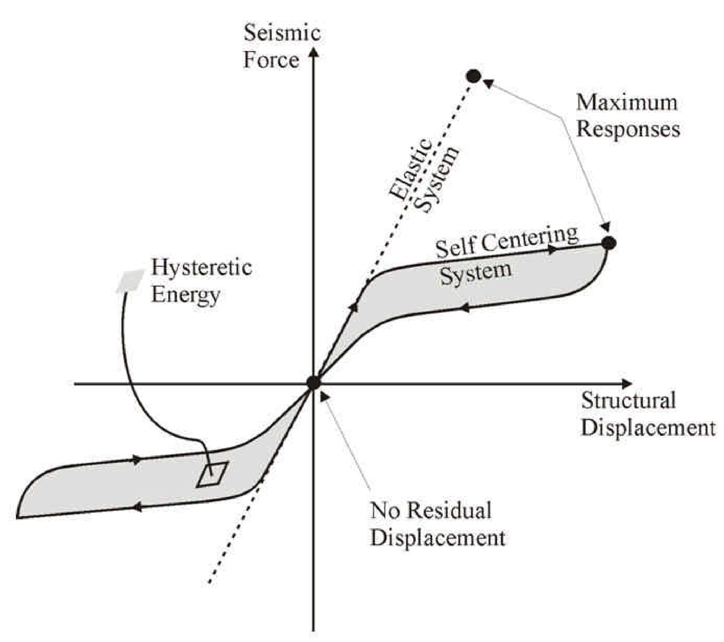

Figure 2. Response of Self-Centering Structures

But the conventional buildings (EPS) didn't consider the economic loss of seismic nonstructural damage. A real case is the seismic damage of buildings during the 1994 Northridge earthquake. With the loss of approximately $18.5 billion due to building damage, non structural damage accounted for about 50% of this total (Kircher, 2003). Furthermore, inelastic deformation and residual drifts will occur in these EP structures after earthquakes.

Self-centering systems, shown in Fig. 2, can be considered to reduce the seismic response and eliminate the residual drift. The seismic response of self-centering systems in fig. 2 can be achieved using special energy dissipating dampers, materials (like shape memory alloy) or special connections. The self-centering systems can not only control the response of the structures but also can reduce the seismic response of nonstructural parts, which decrease the loss of seismic damage more than EP systems.

The common method to analyze responses of a system is to make an numerical analysis on SDOF system. The seismic response of a SDOF system can reflect the properties of MDOF systems (real structures). A numerical parametric study of SDOF self-centering systems under MCEER Ground Motions was conducted in this research.

OBJECTIVES

The objective of this research is to numerically determine the seismic responses of Elasto-Plastic (EP) SDOF systems and Self-Centering (SC) SDOF systems under MCEER Ground Motions, and compare the two responses to achieve better results and save more expenses due to repair the damage of structural and nonstructural components. This research provides also a foundation to the analysis of MDOF self-centering system and to direct the application of self-centering systems in real structures.

METHODS

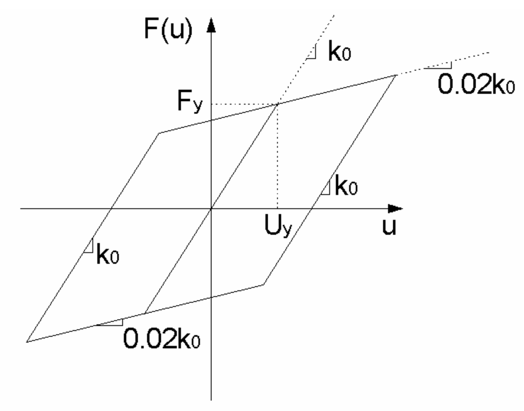

Figure 3. Simplified Elasto-Plastic System

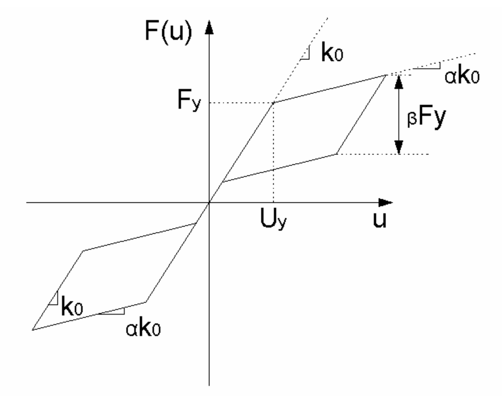

Figure 4. Simplified Self-Centering System

a	ß	?	T_0 (sec)
0.02	0.0	0.05	0.01
0.10	0.3	0.10	0.25
0.20	0.6	0.20	0.50
0.35	1.0	0.30	1.00
		0.50	1.50
		1.00	2.00

Dynamic Equation: $m\ddot{u} + c\dot{u} + F(u) = -m\ddot{u}_g$

A numerical program in Matlab was developed to compute the seismic responses of SDOF Elasto-Plastic (EP) and Self-Centering (SC) systems using Newmark's time-integration method with Newton-Raphson iteration. The input excitations are 25 MCEER Ground Motions. And the SC system was computed with different parameters: a, ß, ? (=Fy/mg, strength factor), T_0 (Natural Period).

RESULTS

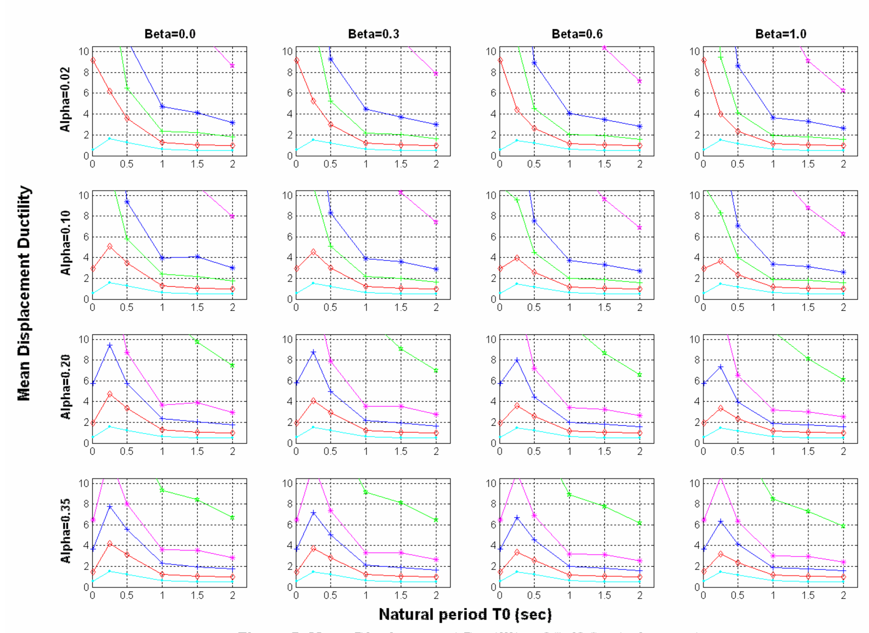

Figure 5. Mean Displacement Ductility of Self-Centering systems

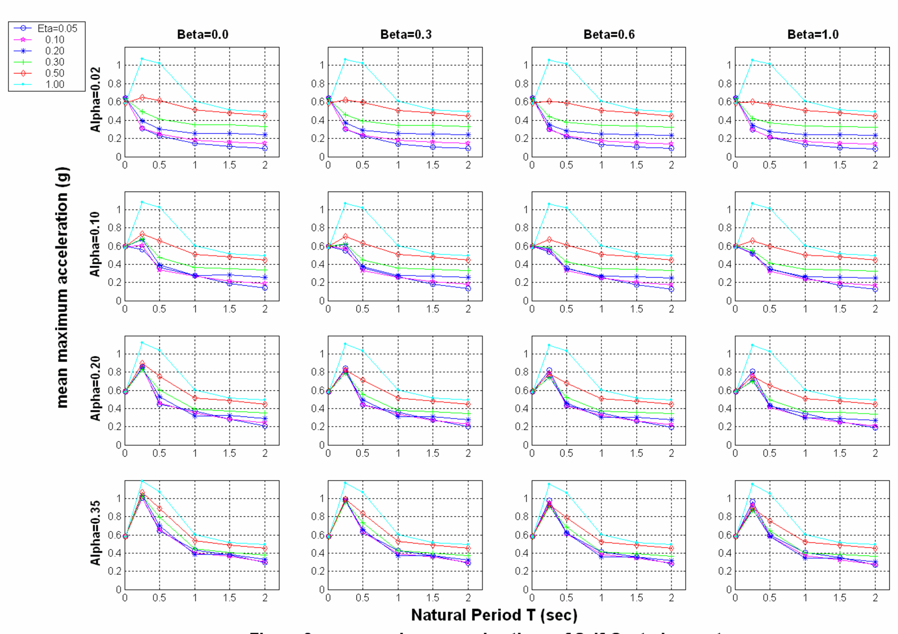

Figure 6. mean maximum accelerations of Self-Centering systems

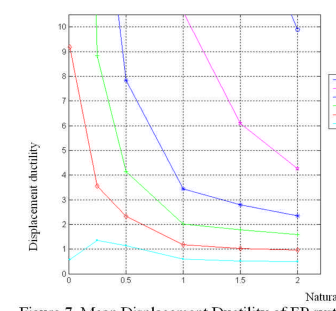

Figure 7. Mean Displacement Ductility of EP systems

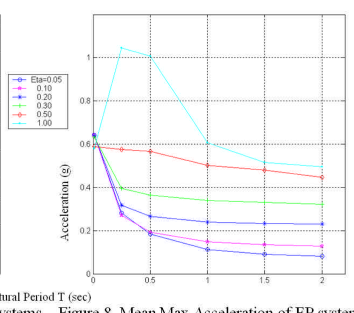

Figure 8. Mean Max Acceleration of EP systems

Mean displacement ductility and mean absolute acceleration are shown in Figs 5, 6 for SC systems and Figs 7, 8 for EP systems. The responses of Self-Centering system were compared against those of Elasto-Plastic system with similar period and post-tensioned coefficient a=0.02.

CONCLUSIONS

1. The self-centering system could achieve similar or better responses than conventional buildings (Elasto-plastic system).

2. Residual drift in the self-centering system is eliminated due to the self-centering compatibility, which reduces the cost of repairing the seismic damage of structures.

3. Using different parameters in Self-Centering systems, the different demands (displacement-sensitive or acceleration-sensitive) of nonstructural components can be satisfied.

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