Seismic Response of Steel Framed Hospital Buildings with Self-Centering Systems

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ABSTRACT

The concepts of Elasto-Plastic Systems (EPS) and Self-Centering Systems (SCS) for the seismic design of steel framed hospital buildings are introduced. Re-design of the MCEER West Coast Demonstration Hospital with SCS is conducted using this approach. An ensemble of 25 simulated MCEER Ground Motions having a probability of exceedence of 5% in 50 years in Northridge, California is used as earthquake excitations in the seismic analysis of the building. The SCS are achieved by Post-Tensioned Energy-Dissipated (PTED) beam-to-column connections. The redesign procedure is briefly outlined. With a set of optimal designed parameters for the SCS, the structural system achieves very good seismic performance. Not only the maximum displacements are reduced but also the floor accelerations are diminished, which is rarely achieved with other passive hysteretic control systems, such as friction or metallic dampers. Also, residual drifts are reduced largely or eliminated, which will decrease the cost to repair. The improved performance obtained suggests that the implementation of SCS can lead to improve seismic behavior at a reasonable cost.

BACKGROUND

Steel Moment Resisting Frames (SMRF) have been widely used in North America and the world until the brittle failures of bema-to-column joints observed in a large number of SMRF as a result of the 1994 Northridge earthquake. Approximately 100 SMRF structures experienced beam-to-column connection fractures in the Northridge earthquake. To avoid that the damage occurs in future earthquakes, on one hand, many research efforts were conducted to upgrade the earthquake codes by SAC joint venture. Other parallel research was initialed by the Federal Emergency Management Agency (FEMA). It is believed that the post-Northridge buildings have the better seismic performance than prior-Northridge building due to the current code. On the other hand, the old structures designed with the old codes prior to the Northridge earthquake need to be re-design. Many retrofit methods were studied to get better seismic response than that of the original buildings. The main retrofit method is the passive control including the viscous damper, friction damper, base isolation, tuned-mass damper and self-centering systems.

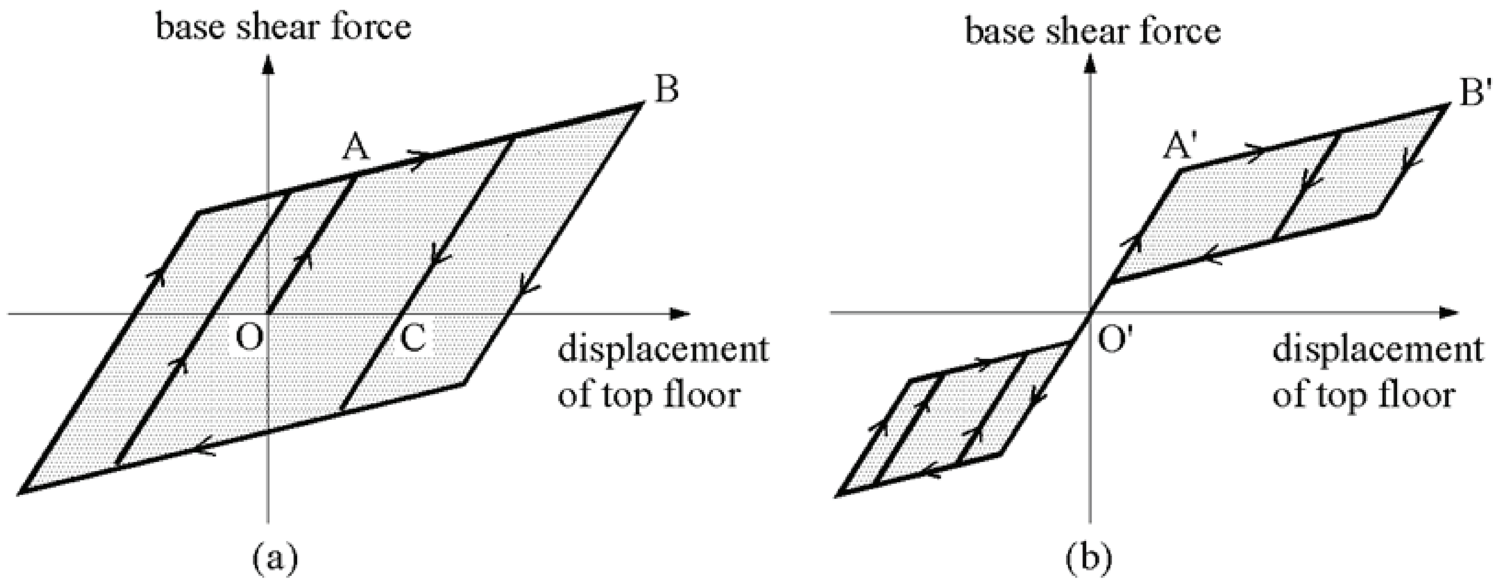

Figure 1. (a) Ideal inelastic seismic response of Elasto-Plastic Systems (EPS)
(b) Ideal seismic response of Self-Centering Systems (SCS)

The seismic responses of Conventional SMRF (EPS) and SCS are indicated in Fig. 1. Based on the seismic results of Single-Degree-of-Freedom (SDOF) SCS and EPS obtained through the previous research, SCS was implemented in the re-design of a Multi-Degree-of-Freedom (MDOF) system, the MCEER Demonstration Hospital (WC70). The seismic performance of the re-designed hospital was evaluated in this research.

OBJECTIVES

The objectives of this research are to demonstrate that the previous results of SDOF SCS can be used to re-design the SMRF with SCS, to propose a re-design method for implementing SCS to SMRF, and to compare the seismic performance of the original hospital and the re-designed one. Also, the author expects the results of research can prompt the practice of SCS and the re-design method can be used by the industry.

METHODS

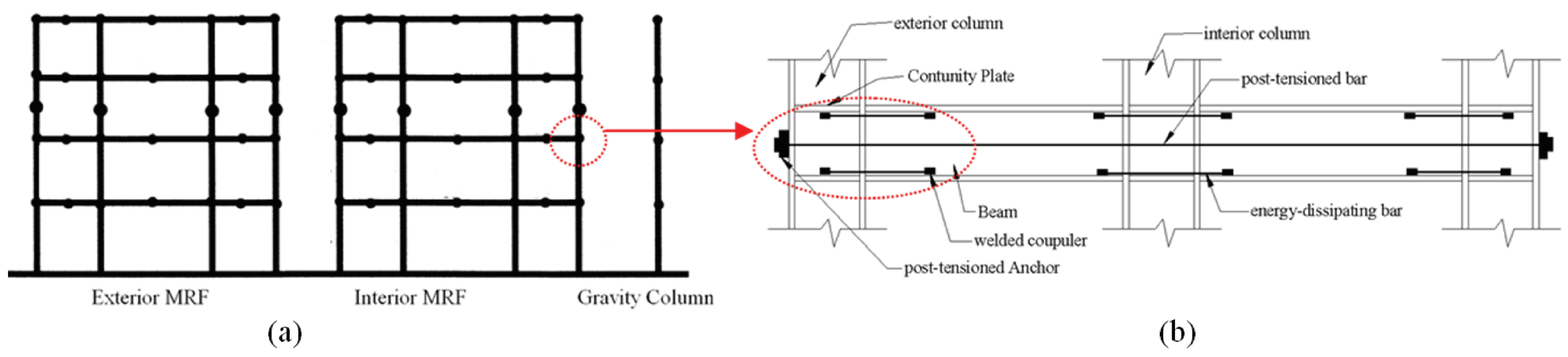

Figure 2. (a) 2-Demensional Numerical Model of SMRF (b) Interior and Exterior Post-Tensioned Energy-Dissipating Connections

First of all, according to the proposed re-design procedure, the original SMRF building was re-designed with SCS, which is implemented by PTED connections as indicated in Fig. 2(b). Then, two 2-dimenion numerical models were constructed for the original building and re-designed building as shown in Fig. 2(a). At last the seismic performance of two models were compared through the results of seismic analysis under the 25 simulated MCEER Ground Motions with 5% exceedance probability in 50 years in Northridge.

RESULTS

Table 1. Responses of Seismic Analysis of the original hospital (an Elasto-Plastic system, EPS) and the re-designed hospital with Self-Centering System (SCS)

Mean Value of responses of 25 earthquakes		Original Hospital (EPS)		Re-designed hospital (SCS) α=0.05 β=0.8 η(original)/ η(retrofit)=0.5	
	unit	mm	%	mm	%
Max Displacement	top floor	205.46	1.32	189.14	1.22
Residual Displacement	top floor	42.47	0.27	6.17	0.04
Max Interstory Drift	1st floor	73.52	1.78	59.35	1.44
	2nd	67.14	1.76	58.71	1.54
	3rd	53.66	1.41	47.70	1.25
	4th	34.55	0.91	29.10	0.76
Residual Interstory Drift	1st	16.34	0.40	4.73	0.11
	2nd	14.15	0.37	0.88	0.02
	3rd	10.30	0.27	0.68	0.02
	4th	2.56	0.07	0.04	0.00
Acceleration Unit		g		g	
Max Absolute Floor Acceleration	1st	1.05		0.76	
	2nd	1.01		0.76	
	3rd	1.04		0.82	
	4th	1.41		1.06	

CONCLUSIONS

1. The seismic analysis indicates that the seismic performance of MCEER hospital re-designed with Self-Centering Systems (SCS) is much better than that of the original hospital.

2. Both the maximum displacements and absolute floor accelerations are reduced which is rarely reported in other passive control retrofit methods

3. The previous results of Single-Degree-of-Freedom SCS can be used as a design guideline to select optimal SCS parameters for the re-design.

4. The residual drifts of the building re-designed with SCS can be reduced or eliminated, which save lots of cost to repair the structures after an earthquake hazard.

ACKNOWLEDGEMENTS

This study was carried out under well appreciated guidance of the Principle Investigator, Professor André Filiatrault, and primarily supported by the Earthquake Engineering Research Centers Program of the National Science Foundation, under award number EEC-9701471 to the Multidisciplinary Center for Earthquake Engineering Research. Any opinions or conclusions presented in this poster are those of the author and do not necessarily reflect the views of the sponsors.