INVESTIGATION OF DETERIORATION BEHAVIOR OF HYSTERETIC LOOPS IN NONLINEAR STATIC ANALYSIS FOR SCMR FRAMES WITH SHEAR WALLS

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One of the shortages of pushover analysis is that it approximately considers the effects of deterioration pertained to hysteretic loops for structural elements. Many studies have been done for evaluation and improvement of this method considering cyclic loading and deterioration parameters. Among all, Akkar and Metin (2007), Goel and Chadwell (2007), Lin and Miranda (2009), Amiri et al. (2010) and Jaiyong and Chintanapakdee (2011) can be referred to. Song and Pincheira (2000) started studying the effects of strength and stiffness degradation on SDOF systems. In a part of their study, they evaluate the displacement coefficients method suggested by FEMA 273. The results have shown that the amounts of displacement coefficients C_1, C_2 and C_3 in FEMA 273, for the systems with periods equal or greater than 0.3 second are more conservative under earthquake excitations on hard soil. Of course it is not the same for the systems which their periods are smaller than 0.3 second and the structure may experience a larger displacement. Furthermore, in order to improve the inelastic seismic analysis procedures, extensive studies on different soil types have been done by Miranda and presented in ATC55 that leaded to publishing FEMA 440.

According to the research purpose, studying the deterioration behavior of hysteretic loops, it is necessary to perform nonlinear static and dynamic analyses and compare the results. To this end, six different planar frames, each one being a part of three-dimensional designed structures, have been modeled. All of the structures are the same in plan and different in height. Because OPENSEES software benefits from various behavioral characteristics for steel and concrete, and also has the ability to suitably model the structural elements, it has been used for performing nonlinear analyses. The employed material models are REINFORCING STEEL MATERIAL, CONCRETE02 and HYSTERETIC MATERIAL. For modeling the structural elements, stresses and strains for each designed section are considered with respect to confinement effects. The required backbone curve includes cracking, yielding and ultimate stress points which are all derived from USC-RC software, and of course with considering elements cross section, arrangement, number and size of reinforcing bars. After conducting the pushover analyses, in accordance with the displacement coefficients method in FEMA 356 and Publication No. 360, for defining the target displacement, dynamic analyses are also performed considering Deterioration behavior and non-degrading behavior. It is worth mentioning that nonlinear dynamic analyses have been done for 0.35g hazard level. This hazard level is derived by scaling the applied ground motions according to the Iranian Code of Practice for Seismic Resistant Design of Buildings, No. 2800. In order to specify the capacity curve of the structure, the displacement of the control node and the shear force of the base level were computed by OPENSEES software. For accurate calculation of the target displacement and bilinear idealization of capacity curve, a computer program was developed in MATLAB environment to determine the target displacement, strength ratio (R) etc, which its derived parameters have been presented in Table 1.

Finally, maximum displacement amounts derived from inelastic dynamic analyses for 0.35g hazard level are compared with those obtained from nonlinear static analyses, δ_t, which express the maximum displacement of the structure under design earthquake, and consider the effects of different parameters such as deterioration with the coefficient c_2. Results show that with increasing the height of frame, the variance between frame displacements with both deteriorating and non-degrading behavior will be decreased, so that the effect of deterioration behavior could be neglected in target displacement calculation for high-rise frames, Figure 1.

Table 1. Derived parameters from MATLAB

Frame	period T (s)	Effective period T_e (s)	Target displacement δ_t (mm)	Final Target displacement $\delta_{t\ final}$ (mm)	δ_y (mm)	Strength ratio (R)	δ_{tf}/δ_t	δ_{tf}/δ_y
3-story	0.251	0.252	20.72	20.88	8.80	1.48	1.008	2.373
5-story	0.460	0.462	60.65	61.20	18.10	2.05	1.009	3.381
7-story	0.660	0.663	107.83	108.94	31.90	2.22	1.010	3.415
10-story	0.996	1.006	187.66	190.15	62.80	1.95	1.013	3.028
15-story	1.954	1.990	460.90	472.25	178.40	1.19	1.025	2.647
20-story	2.676	2.714	700.95	714.25	269.80	1.11	1.019	2.647

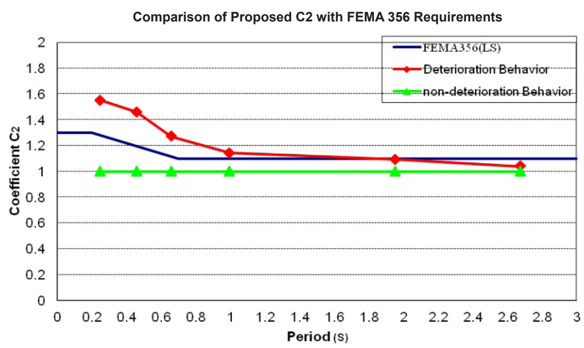

Figure 1. Comparison of proposed C_2 by FEMA 356 requirements

REFERENCES

Akkar S and Metin A (2007) Target assessment of improved nonlinear static procedures in FEMA- 440, *Journal of Structural Engineering (ASCE)*, 133(9): 1237-1246

Amiri GG, Mohebi B and Amrie SAR (2010) Challenges, Opportunities and Solutions in Structural Engineering and Construction- chapter 7(Cyclic loading deterioration effect in RC moment frames in pushover analysis), Taylor & Francis Group, London, UK

ATC 55 (2002) Applied Technology Council, Evaluation and Improvement of Inelastic Seismic Analysis Procedures, Redwood City, California

Esmaeily A (2008) USC-RC Manual: A program for analysis of reinforced concrete members, Berkeley, University of Southern California

FEMA 273 (1997) Federal Emergency Management Agency, NEHRP Guidelines for the Seismic Rehabilitation of Buildings, Washington DC

FEMA 356 prestandard (2000) Federal Emergency Management Agency, Prestandard and commentary for the seismic rehabilitation of buildings, Washington DC

FEMA 440 (2005) Federal Emergency Management Agency, Improvement of Nonlinear Static Seismic Analysis Procedures, Washington DC

Goel RK and Chadwell C (2007) Evaluation of current nonlinear static procedures for concrete buildings using recorded strong-motion data, Department of Civil & Environmental Engineering, California Polytechnic State University, San Luis Obispo

Jaiyong A and Chintanapakdee C (2011) Target roof displacement of degrading moment-resisting frames, *The IES Journal Part A*: Civil & Structural Engineering, 4(4): 232-244

Lin YY and Miranda E (2009) Evaluation of equivalent linear methods for estimating target displacements of existing structures, *Journal of Engineering Structures,* 31, 3080-3089

Mazzoni S, McKenna F, Scott MH and Fenves GL (2007) OPENSEES Command Language Manual, Berkeley, University of California

Publication No. 360 (2007) Instruction for seismic rehabilitation of existing buildings, Technical criteria codification & earthquake risk reduction affairs bureau, Office of deputy for technical affairs, Management and planning organization, Tehran

Song JK and Pincheira J (2000) Spectral displacement demands of stiffness and strength-degrading systems, *Earthquake Spectra*, 16(4): 817-851

Standard No. 2800 (2005) Iranian code of practice for seismic resistant design of buildings (third ed.), Building and Housing Research Center, Tehran