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EVALUATION OF SEISMIC PERFORMANCE OF STEEL MOMENT FRAMES CONSIDERING DETERIORATION EFFECTS USING IDA

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In recent decades several destructive earthquakes resulted in extensive structural and non-structural damage in structures which was produced due to strength and stiffness degradation of structural elements. On the other hand, steel structures are generally modeled considering an elasto-plastic behavior with strain hardening which may be overestimated performance of structure. Therefore, it reveals the necessity for the accurate estimation of deterioration of both the strength and stiffness of elements, affecting the overall structural performance under seismic loading (Ribeiro et al., 2014).

The main purpose of this paper is to assess seismic performance factors of steel moment frames with and without deterioration effects, utilizing incremental dynamic analysis (IDA) and FEMA P-695 methodology accurately. At least, the authors would like to present precise compare of modified Ibarra and Krawinkler (2005) model and an elasto-plastic model with strain hardening to simulate beam behavior of steel structures. For this purpose, two-dimensional models of 3, 9, and 20-story of SAC steel moment frames are implemented in the OpenSees framework.

All models included a leaning column with no lateral stiffness to account for P-Delta effects. In this study 2% Rayleigh damping has been used. Columns are modeled using fiber elements, which effectively simulate interaction between axial force and moment. The behavior of the fiber elements is represented by a bilinear model with a 3% strain hardening. The columns in the 3-story are assumed to be fixed at the ground floor level, and the columns in the 9- and 20-story are assumed to be pinned at the basement level. Beams are modeled to behave in an elastic range. Nonlinear behavior of beams, as shown in Figure 1, is represented by zero-length plastic hinge springs placed at the ends of each beam, considering elasto-plastic behavior with strain hardening and a bilinear model with deterioration where My and Mc are the yield and capping moment strengths, respectively, while θp and θc are the plastic and capping rotation capacity, which can be calculated using the regression equations proposed by Lignos and Krawinkler (2011).

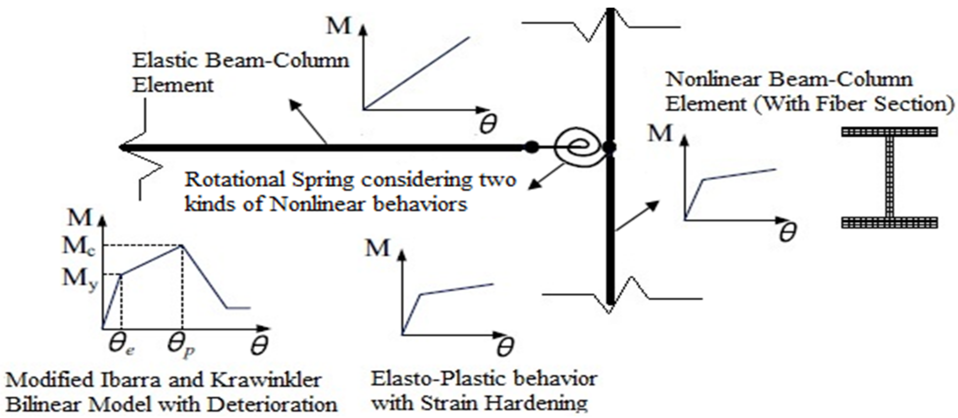

Figure 1. Analytical model.

The first natural periods of the 3, 9 and 20-storey structures are: 1.02, 2.35, and 4.01 sec, respectively. The analytical models are validated using pushover curves presented by FEMA 355c (2000a) and Ribeiro et al. (2014). Also, these curves are used to compute the system overstrength factor (Ω_0) and period-based ductility (μ_T). Each frame was analyzed using the incremental dynamic analysis (IDA) procedure suggested by FEMA P-695 with the set of 44 far-field ground motion records. IDA curves of structures are presented in Figures 2 and 3. The median collapse spectral intensity, S_{CT}, was taken as the median spectral acceleration at the first mode period, T1. Values of Ω_0 and μ_T, and collapse margin ratio, CMR, are summarized in Tables 1 and 2.

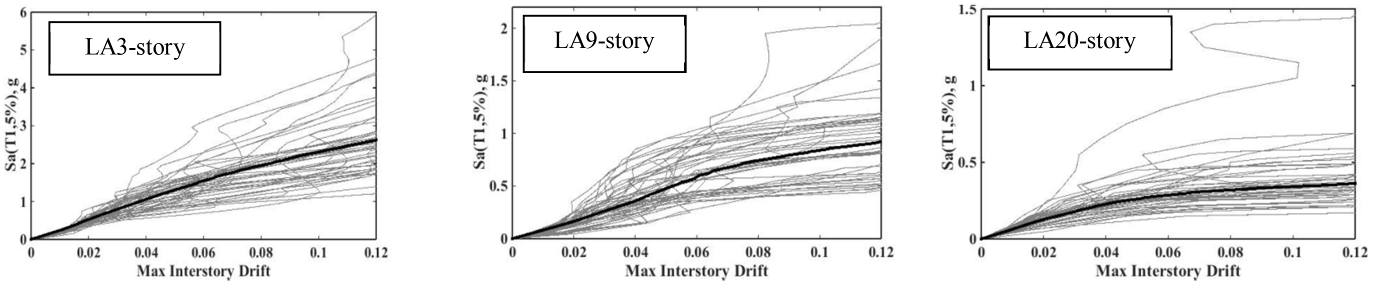

Figure 2. IDA and median curves of SAC buildings with elasto-plastic behavior.

Table 1. FEMA P695 evaluation results of SAC buildings with elasto-plastic behavior.

Building	$\delta_{y,eff}$ (m)	δ_u (m)	μ_T	Ω_0	S_{MT}	S_{CT}	CMR	SSF	ACMR	$ACMR_{,10\%}$	
3-story	0.13	0.36	2.73	3.5	0.88	2.5	2.84	1.24	3.52	2.53	Pass
9-story	0.41	1.11	2.7	3.62	0.39	0.89	2.28	1.3	2.97	2.53	Pass
20-story	0.53	1.73	3.24	2.5	0.22	0.36	1.64	1.34	2.20	2.53	Fail

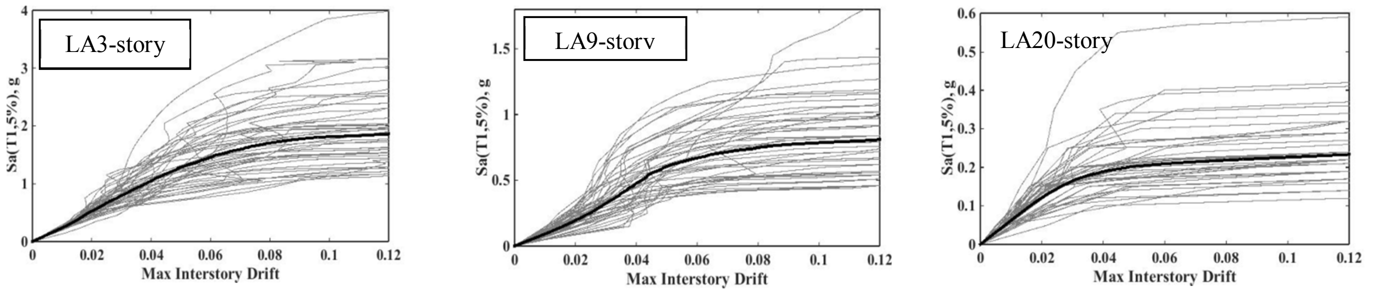

Figure 3. IDA and median curves of SAC buildings with bilinear with deterioration behavior.

Table 2. FEMA P695 evaluation results of SAC buildings with bilinear with deterioration behavior.

Building	$\delta_{y,eff}$ (m)	δ_u (m)	μ_T	Ω_0	S_{MT}	S_{CT}	CMR	SSF	ACMR	$ACMR_{,10\%}$	
3-story	0.13	0.36	2.73	3.5	0.88	1.8	2.05	1.24	2.53	2.53	Pass
9-story	0.4	1.11	2.78	3.67	0.39	0.81	2.1	1.31	2.75	2.53	Pass
20-story	0.5	1.11	2.21	2.43	0.22	0.23	1.05	1.26	1.31	2.53	Fail

As a result, the collapse capacity of deteriorating frames is about 24% less than when an elasto-plastic model is used for plastic hinge springs at the beam ends. Therefore, disregarding of deterioration effects may overestimate the collapse capacity of steel moment frames.

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