A COMPARISON OF IMPROVED PUSHOVER ANALYSES IN COMPUTING THE SEISMIC RESPONSES OF GEOMETRICALLY IRREGULAR BUILDINGS WITH SETBACK

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A building with a sudden change in the geometry of the frame over the height is entitled as setback building, stepped building or vertically geometrically irregular building. This kind of irregularity causes an abrupt discontinuity in stiffness, strength and mass of the frame creating a complex behavior in the seismic behavior (Humar and Wright, 1977). This paper aims to study the seismic behavior of geometrically irregular buildings with setbacks that the irregularity can cause damage under earthquakes. A total of 28 geometrically irregular steel moment resisting frames of different heights (3 and 9-story frames) were evaluated in this study. An eigenvalue analysis was performed to evaluate the dynamic characteristics of structures. The dynamic characteristics of some frames are given in Table 1. Seismic behavior of the frames was examined by nonlinear time-history analysis using seven ordinary far-field ground motion records that are presented in Table 2. To ensure that structures deform well into inelastic range under the selected earthquake ground motions, the records were scaled up to 0.7g. Due to the rapidly increasing use of pushover analysis in recent years and to account for the effect of higher modes in pushover analysis (Krawinkler and Seneviratna,1998), enhanced pushover analyses including the modal pushover analysis (MPA)(Chopra and Goel, 2004), the upper bound pushover analysis (UBPA)(Jan et al., 2004), the consecutive modal pushover (CMP)(Poursha et al., 2011) and the extended N2 (EN2) (Kreslin and Fajfar, 2011) methods were implemented. Geometrically irregular frames are denoted by hFxyz in the paper that h indicates the number of total stories, F is the first letter of the Frame, and x, y and z imply the number of stories in each span from the left to right.

Table 1. Dynamic Characteristics of the 9-story Buildings

Frame	T_1	T_2	T_3	α_1	α_2	α_3	Γ_2/Γ_1	α_2/α_1	α_3/α_1
9F	1.173	0.42	0.246	0.756	0.118	0.054	0.407	0.156	0.071
9F993	1.081	0.40	0.249	0.661	0.178	0.076	0.491	0.269	0.115
9F933	0.93	0.370	0.237	0.461	0.296	0.122	0.64	0.642	0.264

Table 2. Selective Earthquake Accelerogram Properties

Number	Name	Year	Distance(km)	Magnitude	PGA(g)	Duration(sec)
1	Coalinga/Parkfield -Cholame 5W	1983	47.3	6.4	0.147	40
2	Landers/Glendale – Las Palmas	1992	147.9	7.3	0.071	56.7
3	Imperial Valley/Plaster City	1979	31.7	6.5	0.057	18.745
4	Northridge/Pasadena -N Sierra Madre	1994	39.2	6.7	0.245	19.91
5	Northridge/La Crescenta - New York	1994	22.3	6.7	0.178	29.99
6	San Fernando/Hollywood Stor Lot	1971	21.2	6.6	0.174	28
7	Loma Prieta/Agnews State Hospital	1989	28.2	6.9	0.159	40

The results indicate that the effect of higher modes can be considerable for geometrically irregular frames. The values of the modal effective mass ratio for the second and third modes (α_2 and α_3 in Table 1) increase when increasing the irregularity. Also, two basic parameters influence the seismic response of these structures: position of setback and reduction in area of the setback. The seismic responses of geometrically irregular frames, which have a larger effective modal mass ratio for the second and third modes, are large, and the responses increase by reduction in area of the setback. The results show that the enhanced pushover analysis methods can estimate the seismic demands accurately for geometrically irregular frames with setbacks. The seismic responses of the frames with setbacks and the accuracy of the enhanced pushover analysis methods generally depend on dynamic characteristics and geometrical configuration.

In cases for which the modal effective mass ratio of the second and third modes with respect to that of the first mode increases, the CMP and the MPA are accurate enough. The accuracy of the EN2 method is dependent on the modal effective mass ratio for the first mode, so that the higher the ratio, the more accurate the results. Figure 1 illustrates that accuracy of the EN2 method in the case of the frame 9F993 is more than that for the frame 9F933 because the modal effective mass ratio of the first mode,α_1, for the model 9F993 is greater than that for the 9F933. Also, the accuracy of the UB method depends on the ratio of modal participation factor of the second mode to that of the first mode.

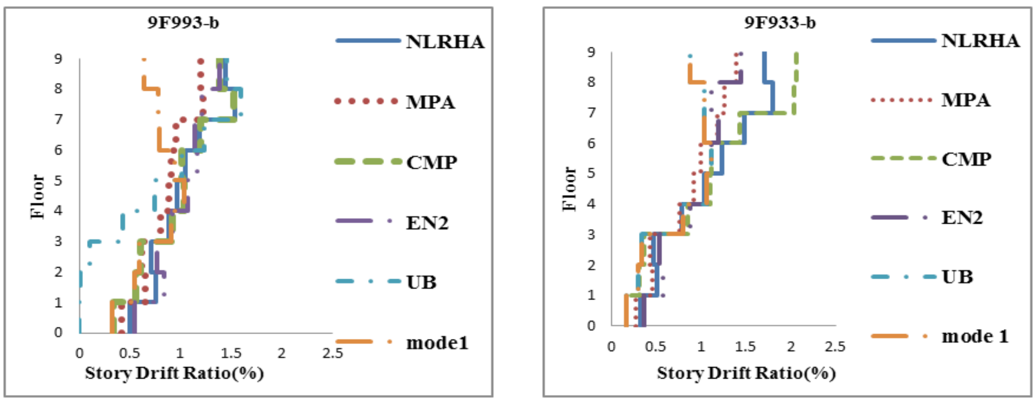

Figure 1. Story Drift Ratio obtained by the MPA, CMP, EN2, UB and NLRHA Methods for the geometrically irregular frames 9F993 and 9F933

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