SEISMIC EVALUATION OF ECCENTRICALLY BRACED STEEL FRAMES DESIGNED BY PERFORMANCE-BASED PLASTIC DESIGN METHOD

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ABSTRACT :

This paper discusses the influence of degrading hysteretic behavior of shear links and P-Delta effect on seismic response of steel Eccentrically Braced Frames (EBF). A 10-story example frame was designed by a newly developed Performance-Based Plastic Design (PBPD) methodology and current code method. The responses of the two frames under inelastic pushover and time history analyses are compared to evaluate the influence of strength degradation of shear links and the P-Delta effect.

KEYWORDS: Performance-based plastic design (PBPD), Plastic design, EBF, Strength degradation, P-Delta effect, Seismic response

1. INTRODUCTION

The structure selected for this study is a 10-story steel building with two bays of eccentric bracing on each side of the perimeter. The 5-bay perimeter EBF was designed by following the requirements of IBC 2000, and by the PBPD method (Chao and Goel, 2006). The PBPD frame was designed for a target drift of 2% for design spectrum with 10% probability of exceedance in 50 years (10%/50yrs), and 3% drift for 2%/50yrs hazard spectrum. The member sizes of the two frames are shown in Figure 1. The frames were modeled and analyzed by using the PERFORM-3D computer Program (CSI, 2007), which has a built-in shear link model. The strength envelopes of the shear links, beams and columns, which include degradation used for modeling are shown in Figure 2. The P-Delta effect was simulated by adding a lumped "gravity column" carrying the tributary design gravity load at each floor level.

2. DISCUSSION OF RESULTS

The PBPD and IBC frames were subjected to inelastic static (pushover) and dynamic time history analyses with and without including the strength degradation and P-Delta effects. The base shear vs. roof drift responses and deflected shapes of the pushover analyses are shown in Figures 3 and 4, respectively. While the peak lateral strength (base shear) achieved in the two frames are almost equal, it appears that post-peak drop is caused more by P-Delta effect in the PBPD frame and by strength degradation in IBC frame, Figures 3a and 3b. The deflected shapes of the two frames at various roof drifts are shown in Figure 4. It can be noticed that the story drifts of the PBPD frame are relatively more uniformly distributed along the height as compared with those of the IBC frame, where large drifts occurred in the upper stories, mainly due to extensive plastic hinging in the columns.

Inelastic time history analyses were carried out by subjecting the two frames to eight SAC LA ground motion records (Somerville, 1997) corresponding 10%/50yrs and 2%/50yrs hazard levels. Absolute minimum, mean, and maximum story drifts are shown in Figure 5. While the story drifts of the two frames are well within the target drifts, the PBPD frame showed somewhat more uniform drift distribution over the height primarily because of limited of flexural yielding in the columns. See Figure 6 for LA 24 ground motion. Another characteristic of the response can be noticed in the distribution of maximum story shears for 10%/50yrs vs. 2%/50yrs ground motions, Figure 7. While the maximum story shears for 10%/50yrs ground motions are close to the PBPD force distribution (Chao et al., 2007), those under more severe 2%/50yrs ground motions show accentuation of story shears in the lower stories of both frames. The authors believe that this may be due to certain characteristics of those ground motions many of which are near fault types.

3. CONCLUSIONS

Following conclusions can be drawn from this preliminary study:

1. Degrading hysteretic behavior of members (especially that of shear links) and P-Delta effect had significant influence on inelastic behavior of EBF designed by PBPD.
2. The response of IBC frame was significantly affected by flexural yielding in the columns.
3. The maximum story shears in both frames were accentuated in the lower stories under more severe ground motions.

ACKNOWLEDGMENTS

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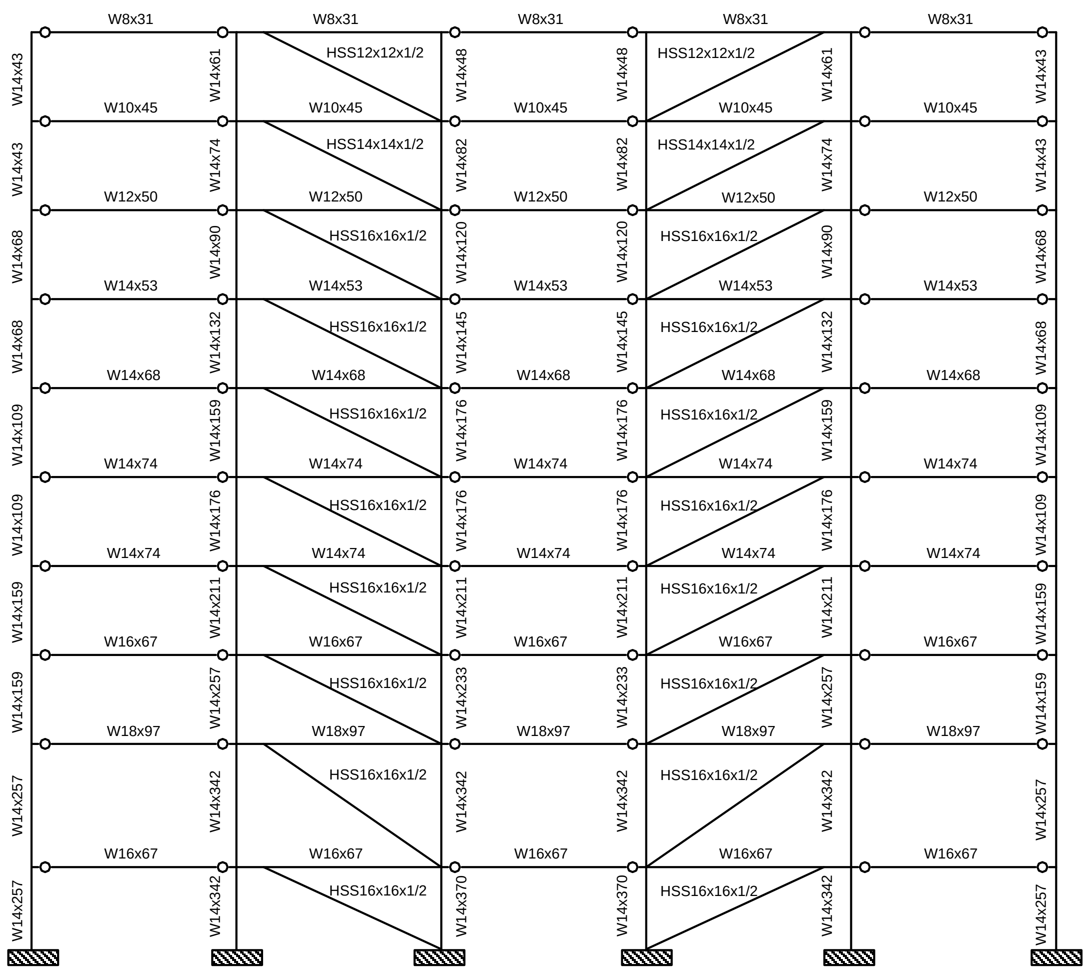
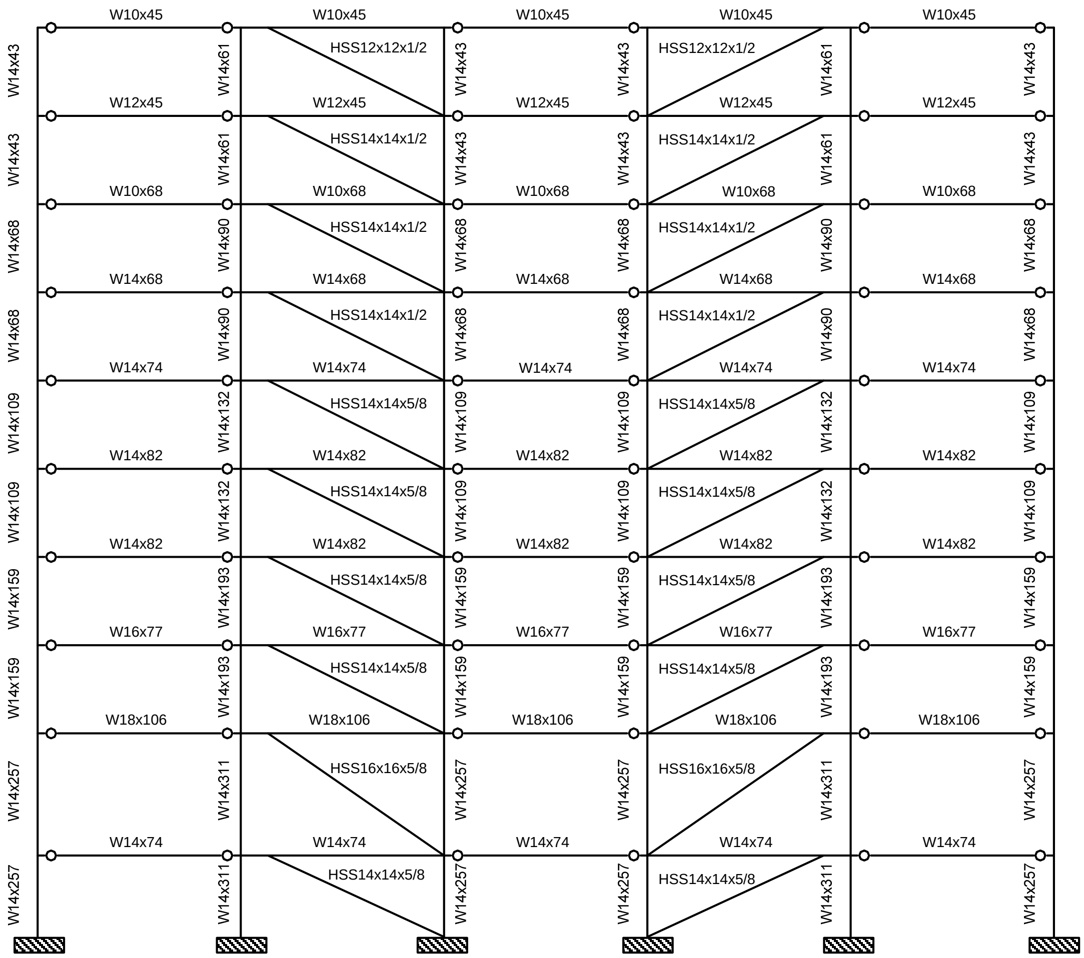


(a) PBPD Frame



(b) IBC Frame

Figure 1 Member sizes: (a) PBPD Frame, (b) IBC Frame

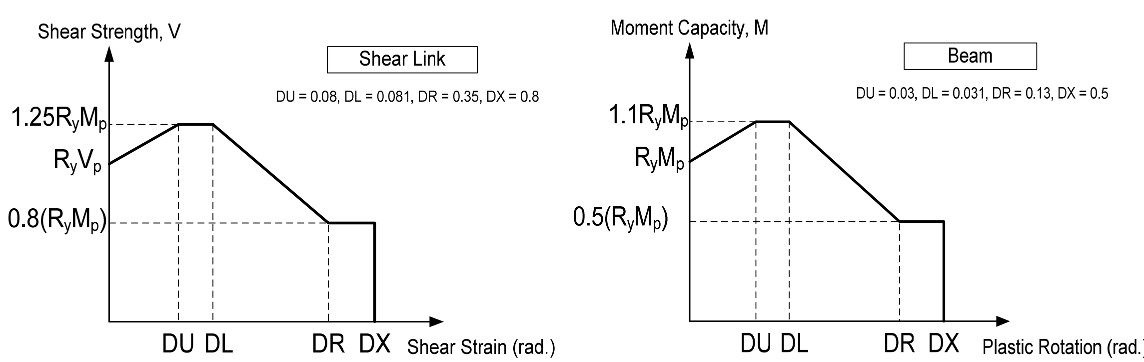


Figure 2 Member strength envelopes for modeling: shear link and beam

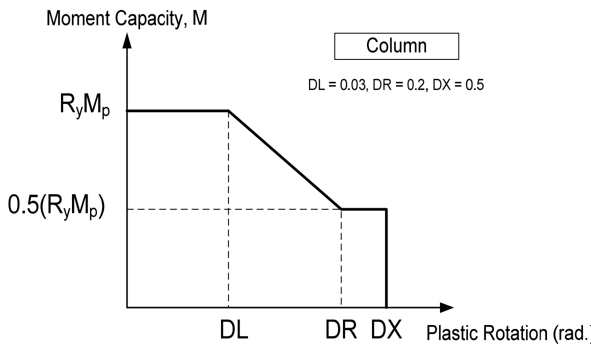
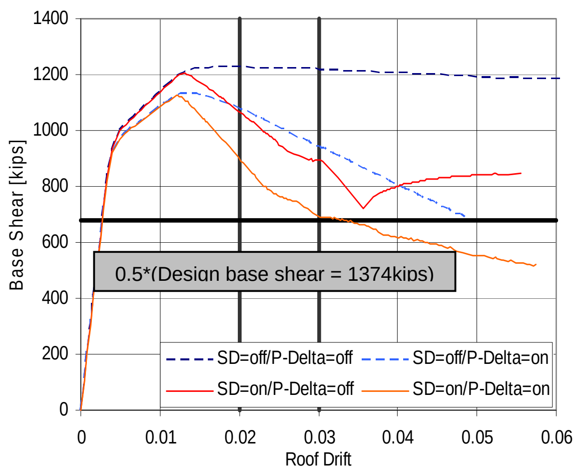
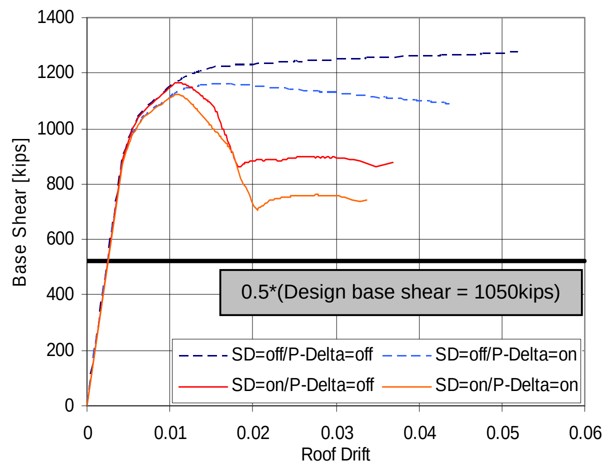


Figure 2 (continued) Member strength envelopes for modeling: column

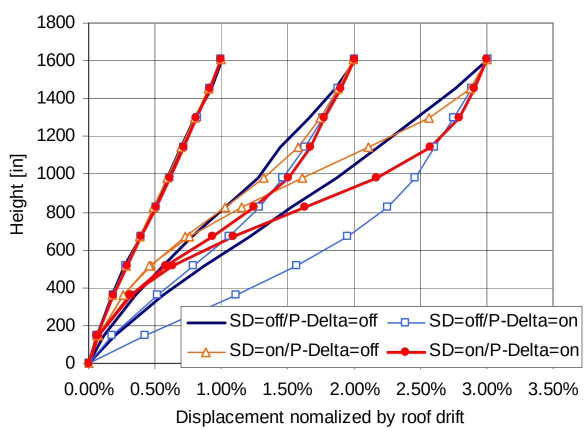


(a) PBPD Frame

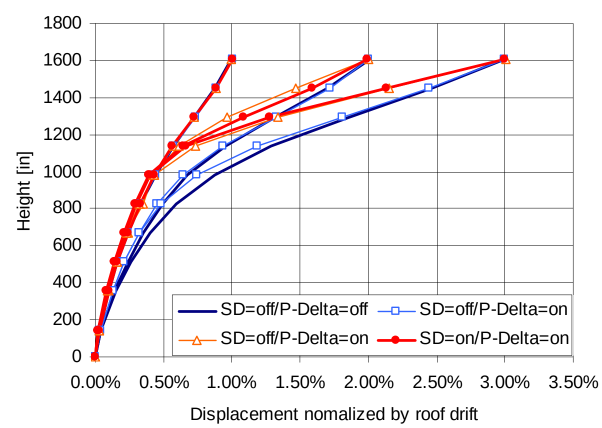


(b) IBC Frame

Figure 3 Base shears vs. roof drift plots from push-over analyses (SD = strength degradation)

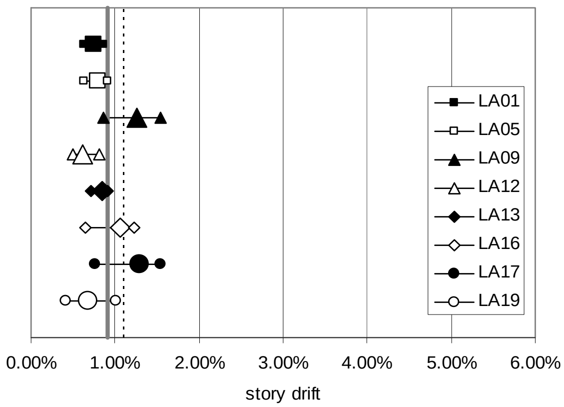


(a) PBPD Frame

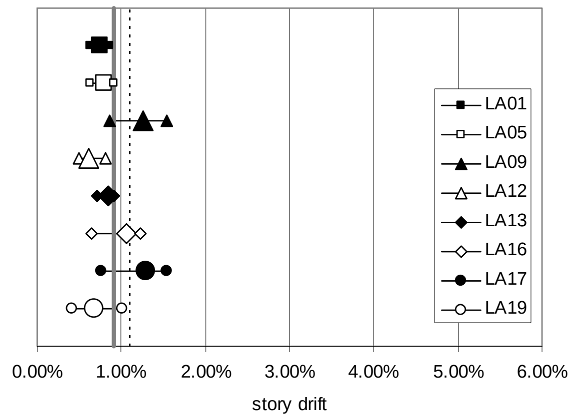


(b) IBC Frame

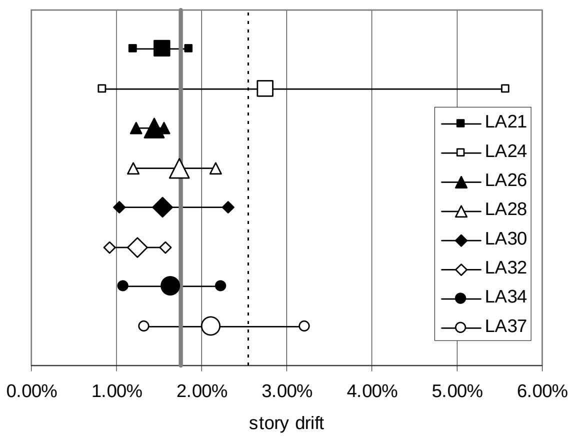
Figure 4. Deflected shapes when the frames were pushed to 1%, 2%, and 3% roof drifts.



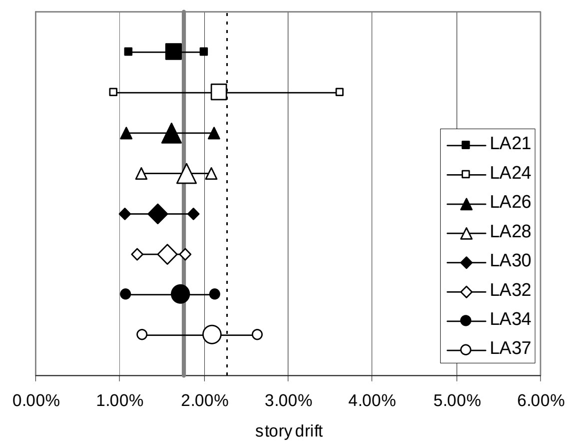
(a) [PBPD 10% in 50 yr] story drift (min-mean-max)



(b) [IBC 10% in 50 yr] story drift (min-mean-max)

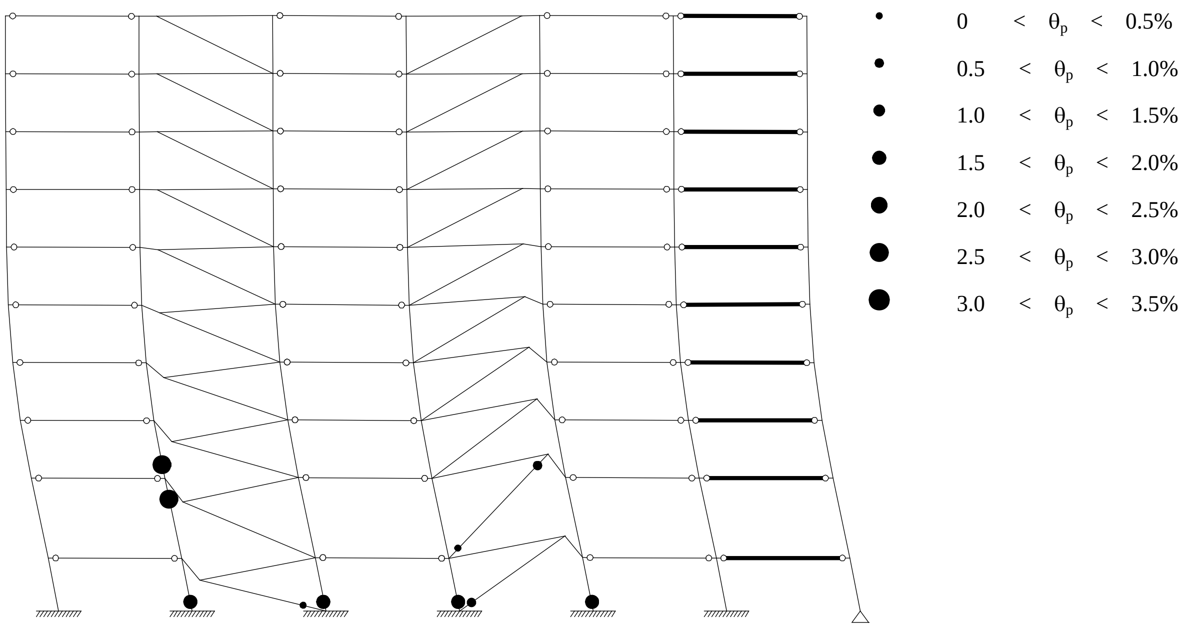


(c) [PBPD 2% in 50 yr] story drift (min-mean-max)

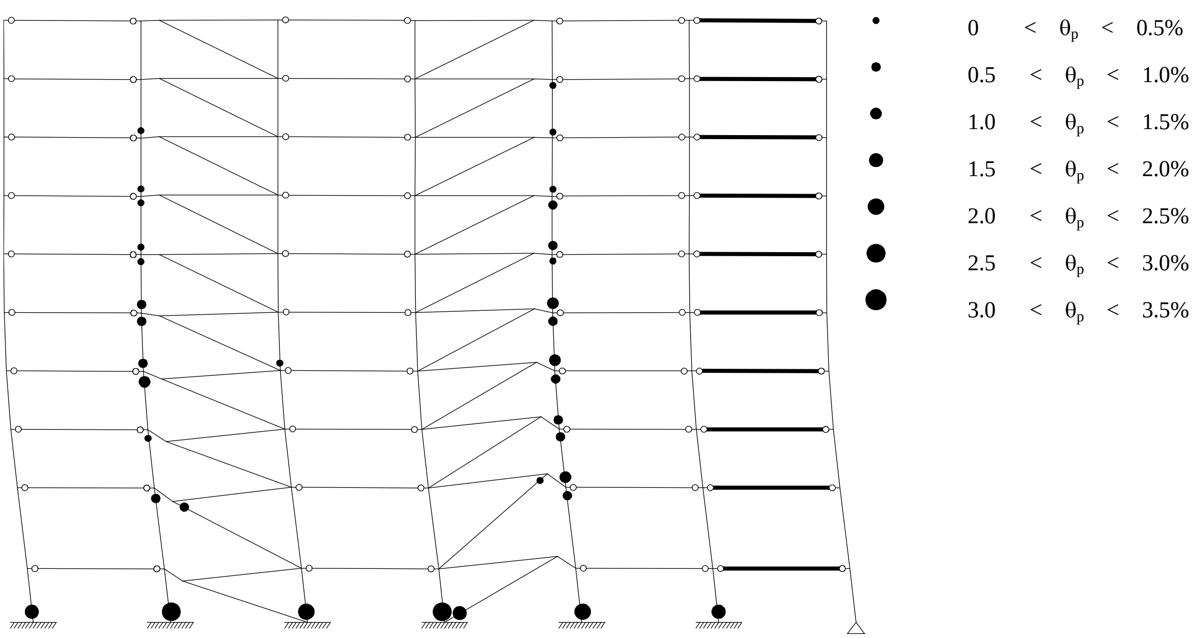


(d) [IBC 2% in 50 yr] story drift (min-mean-max)

Figure 5 Absolute story drifts (minimum-mean-maximum) from nonlinear dynamic analyses

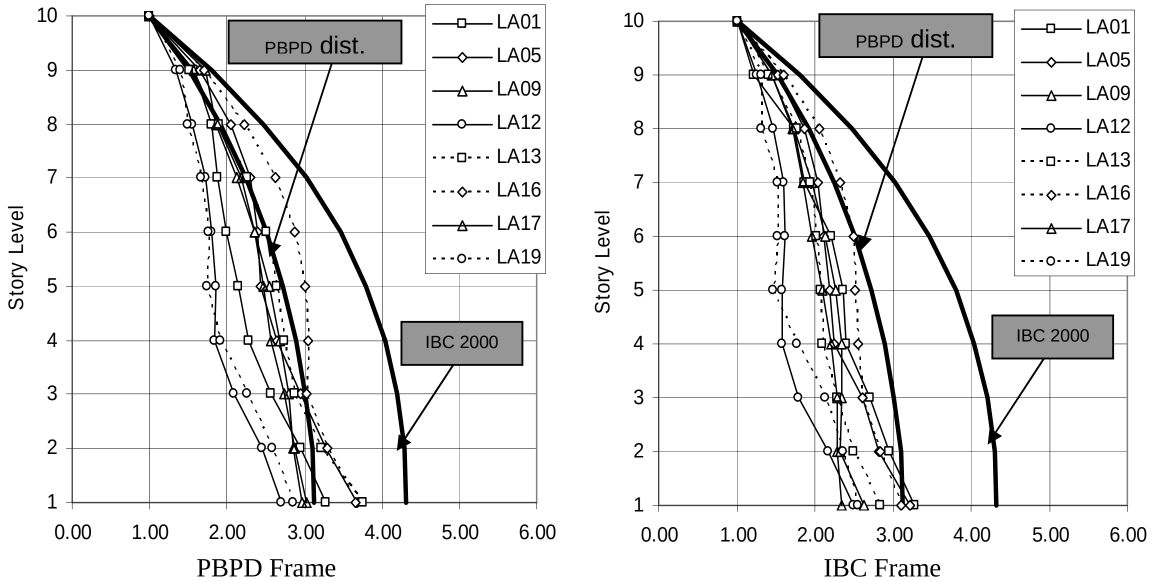


(a) PBPD Frame

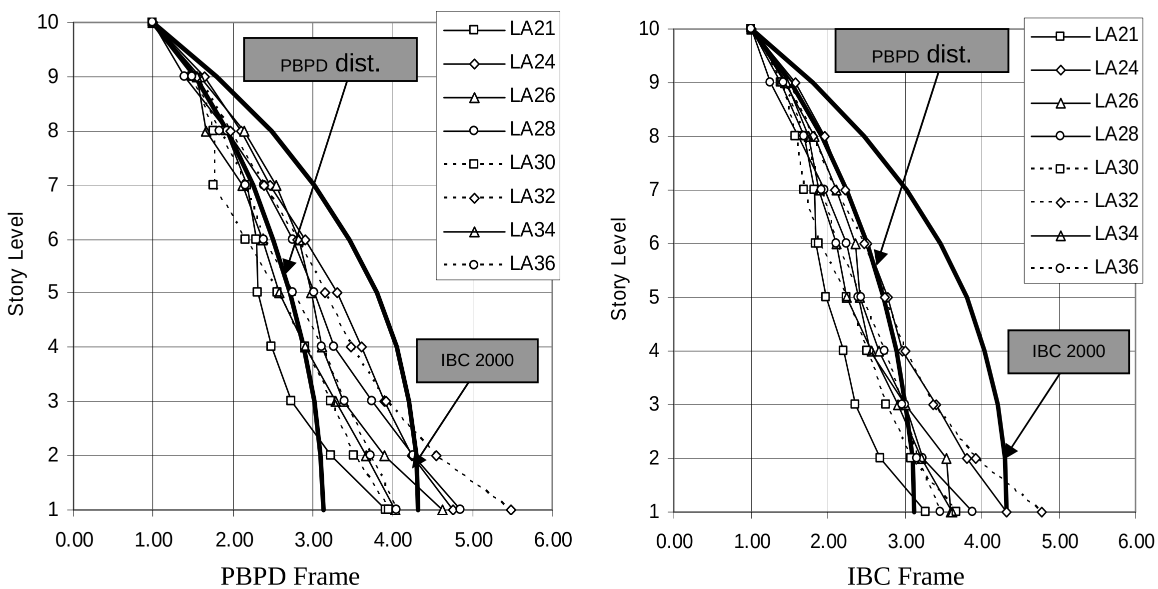


(b) IBC Frame

Figure 6. Member yielding under LA24 ground motion.



Relative distribution of story shear under 10% in 50 years SAC ground motions



Relative distribution of story shear under 2% in 50 years SAC ground motions

Figure 7 Maximum story shear distributions with strength degradation and P-Delta effect included in analysis