Analysis of Steel Panel Dampers for Seismic Applications in Steel Moment Frames

Keh-Chyuan Tsai
Professor of Civil Engineering
National Taiwan University
kctsai@ntu.edu.tw

Summary

This paper introduces the method of using one equivalent beam-column element for effective modeling of the proposed 3-segment steel panel dampers (SPDs). The effects of the IC relative height and stiffness on the overall SPD elastic, post-elastic stiffness, and strain hardening characteristics are discussed.

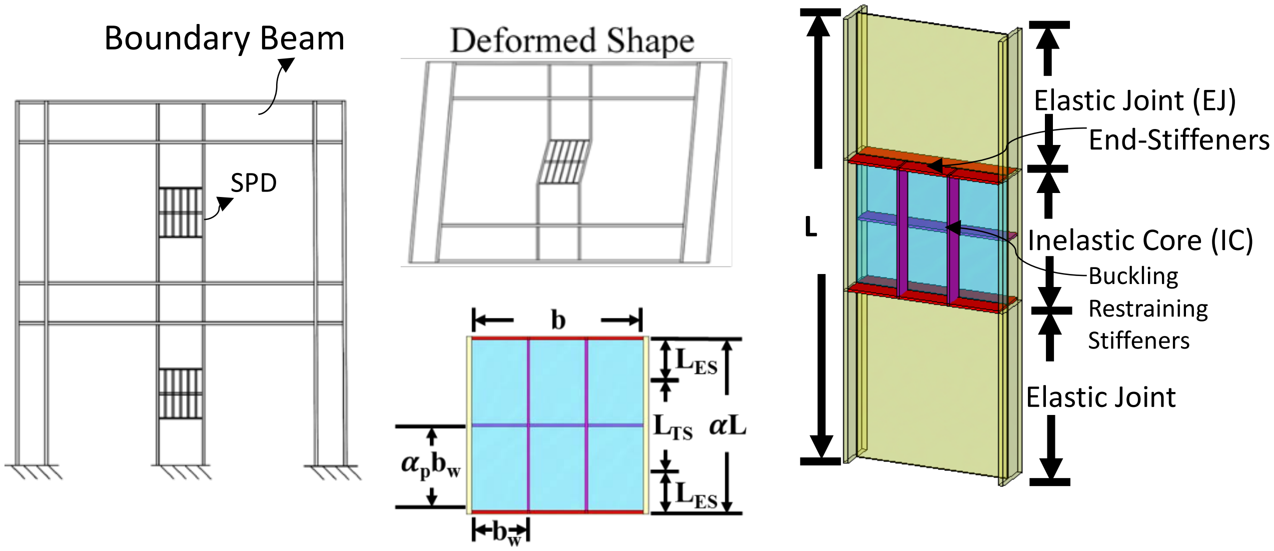


Figure 1 Schematics and stiffener locations of steel panel dampers in the SPD-MRF

(1) Equivalent cross-sectional properties

The shear strength of the SPD can be computed from:

$$V_n = A_{v,IC}\tau_{y,IC} = d_{SPD}t_{w,IC}\tau_{y,IC} = 0.6F_{y,IC}d_{SPD}t_{w,IC} \tag{1}$$

When a 3-segment SPD is represented by one single element, the elastic lateral stiffness of the SPD given in Equation 2 can be substituted by Equation 3:

$$K_{eff} = \frac{1}{1/K_{IC} + 2/K_{EJ}} = \frac{1}{\left[\dfrac{\alpha L}{GA_{V,IC}} + \dfrac{(\alpha L)^3}{12EI_{IC}}\right] + \left[\dfrac{(1-\alpha)L}{GA_{V,EJ}} + \dfrac{L^3-(\alpha L)^3}{12EI_{EJ}}\right]} \tag{2}$$

$$K_{eff} = \frac{1}{\dfrac{L}{G(A_{v,Eff})} + \dfrac{L^3}{12E(I_{Eff})}} = \frac{1}{\dfrac{L}{G(Q_v A_{v,IC})} + \dfrac{L^3}{12E(Q_m I_{IC})}} \tag{3}$$

where $A_{v,IC}$, $A_{v,EJ}$ and $A_{v,,Eff}$ are the shear area of the IC, EJ and the equivalent element; L is the full height of the equivalent element. The I_{IC}, I_{EJ} and I_{Eff} are the moment of inertia of the IC, EJ and the equivalent element. Effect factors *Q* depend on the IC height ratio α and the EJ-to-IC cross-sectional property ratios β_v, β_J, β_A and β_m as expressed in Equation 4 for shear, torsion, axial and bending properties, respectively. A total of six effective factors *Q* must be computed for the SPD, including the effects of the shear in the strong (Q_{vy}) and weak (Q_{vz}) directions, bending in strong (Q_{my}) and weak (Q_{mz}) directions, axial (Q_A) and torsion (Q_J) actions.

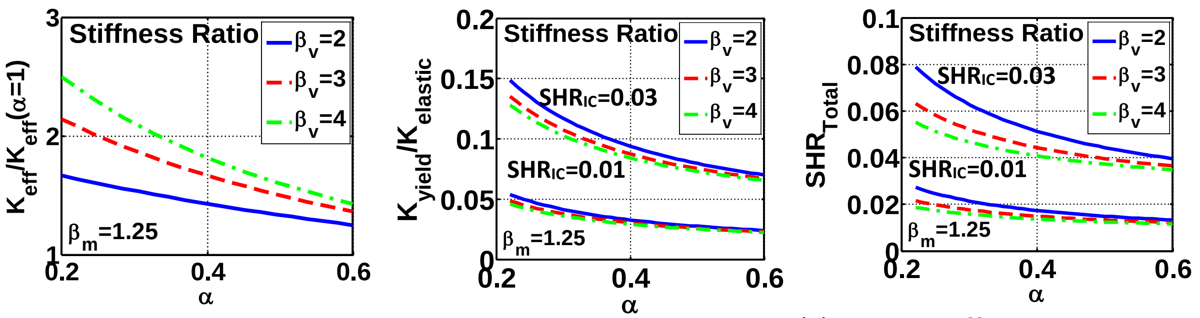
$$\begin{cases} A_{v,Eff} = Q_v A_{v,IC} \\ Q_v = \dfrac{\beta_v}{1+\alpha(\beta_v - 1)} \\ \beta_v = \dfrac{A_{v,EJ}}{A_{v,IC}} \end{cases}, \quad \begin{cases} J_{Eff} = Q_J J_{IC} \\ Q_J = \dfrac{\beta_J}{1+\alpha(\beta_J - 1)} \\ \beta_J = \dfrac{J_{EJ}}{J_{IC}} \end{cases}, \quad \begin{cases} A_{Axial,Eff} = Q_A A_{Axial,IC} \\ Q_A = \dfrac{\beta_A}{1+\alpha(\beta_A - 1)} \\ \beta_A = \dfrac{A_{Axial,EJ}}{A_{Axial,IC}} \end{cases}, \quad \begin{cases} I_{Eff} = Q_m I_{IC} \\ Q_m = \dfrac{\beta_m}{1+\alpha^3(\beta_m - 1)} \\ \beta_m = \dfrac{I_{EJ}}{I_{IC}} \end{cases} \tag{4}$$

These Q factors, applied on the IC sectional properties, are all greater than 1.0. They stand for the effects of relative height and stiffness, α and β factors between the IC and EJ on articulating the effective sectional properties of the equivalent element for the proposed SPD.

(2) Effects of IC height ratio α on the elastic and post-yield stiffness of the SPD

The strength and stiffness of the proposed SPD can be decoupled. Figure 2a shows that the effective elastic stiffness (Equations 2 and 3) of the SPD can be enhanced by more than 100% from reducing the IC height or thickening the EJ webs. Figure 2b shows the effects of the height ratio α on the SPD post-yield to elastic stiffness ratios for ICs with strain hardening ratios of 1% and 3%. Figure 2c shows its effects on the SHR_{Total}. Figures 2b and 2c can be conveniently applied in computing the post-elastic stiffness properties of the entire SPD in simplified structural model analyses.

Reference:
Tsai KC, Hsu CH, Li CH and Chin (2017) "Experimental and Analytical Investigations of Steel Panel Dampers for Seismic Applications in Steel Moment Frames". Earthq. Eng. and Structural Dynamics (in review).



(a) On elastic stiffness

(b) On post-yield stiffness

(c) On effective strain hardening for single element model

Figure 2 Effects of IC height ratio α on the SPD elastic and inelastic stiffness