Seismic Control of Asymmetric Structures

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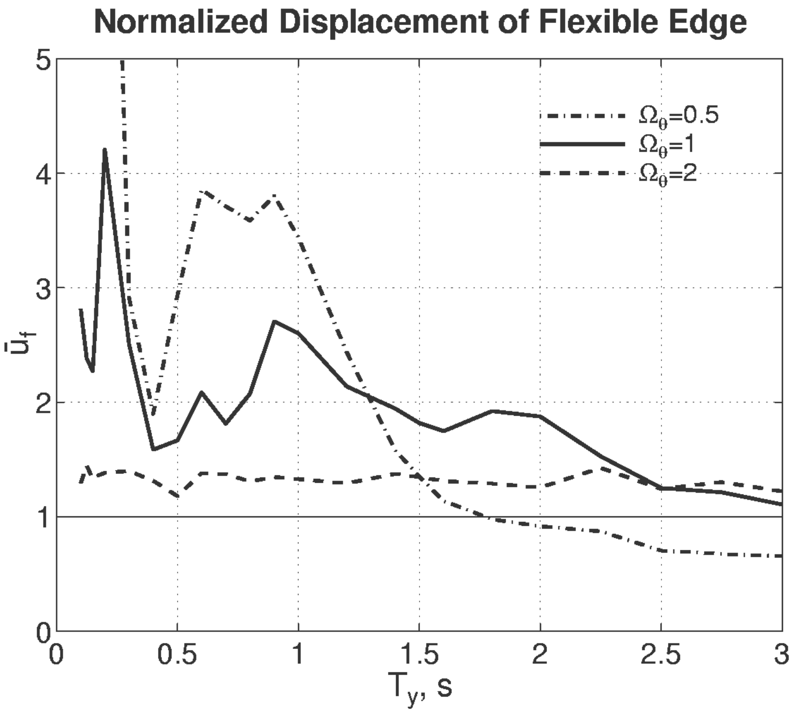
Objectives

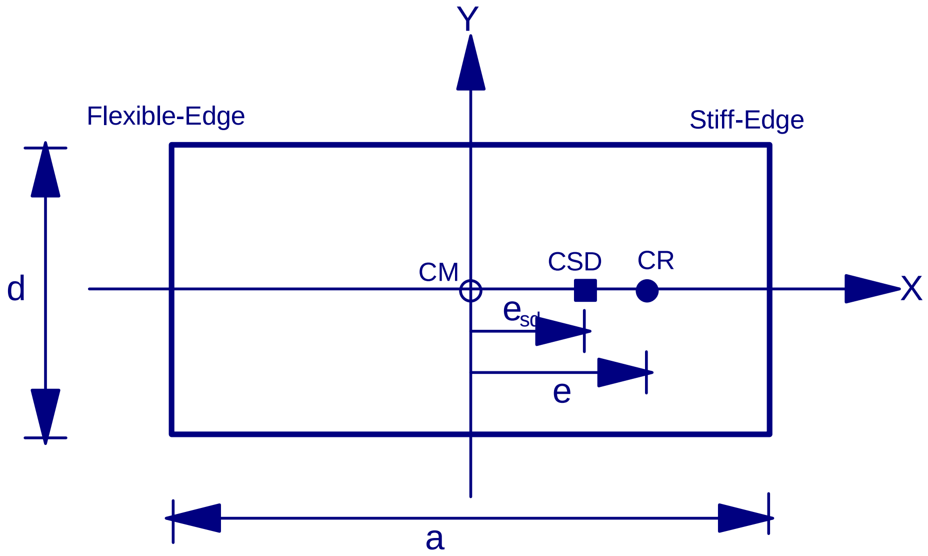
- Systematically investigate effects of viscous supplemental damping on response of asymmetric structures
  - ➔ Identify controlling system parameters
  - ➔ Study effects on deformations
  - ➔ Develop an understanding of key parameters controlling the response
  - ➔ Develop simplified procedure for distributing supplemental damping

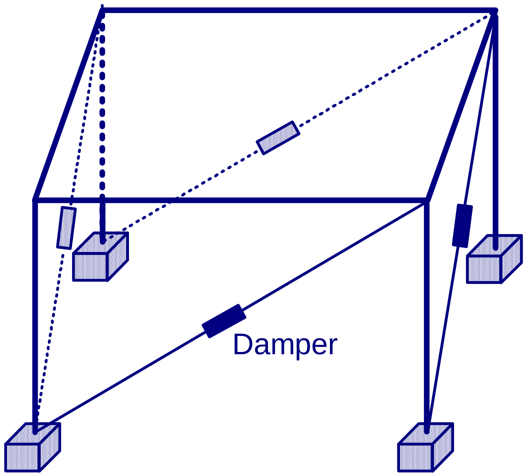
Motivation: Excessive edge deformation in asymmetric structures

- Excessive damage in edge structural/ nonstructural elements
- Increased potential for pounding between adjacent buildings
- Higher second order (P-Δ) effects



System Considered: Simple One-Story Asymmetric System





System parameters without supplemental damping

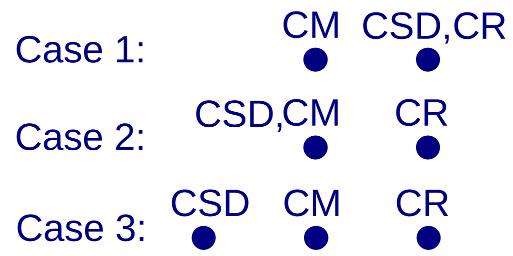
- Lateral period of vibration, T_y
- Stiffness eccentricity $\bar{e}$
- Torsional to lateral frequency ratio, Ω_θ
- Structural damping ratio, ζ

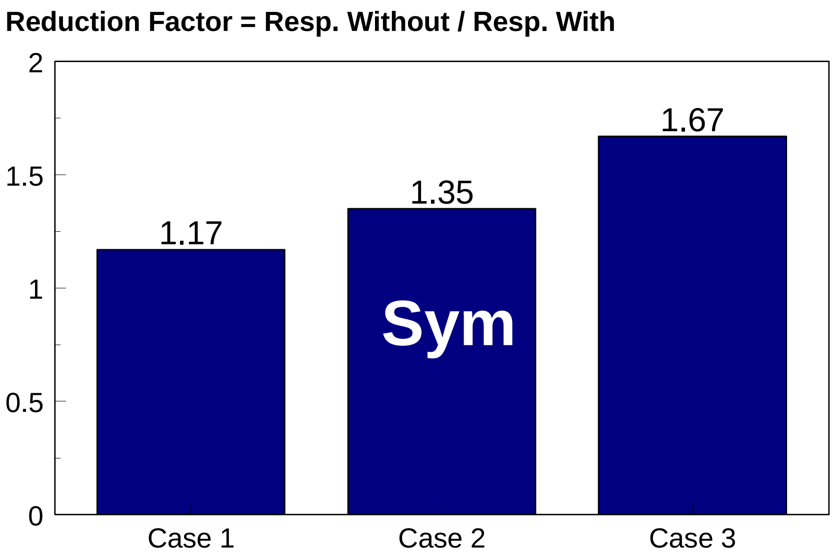
Additional parameters to characterize supplemental damping

- Supplemental damping ratio, ζ_{sd}
  - ➔ Additional damping due to supplemental devices
- Damping eccentricity, $\bar{e}_{sd}$
  - ➔ Location of Center of Supplemental Damping with respect to Center of Mass
- Damping radius of gyration, $\bar{\rho}_{sd}$
  - ➔ Plan-wise spread of supplemental devices

Reduction in edge deformation due to asymmetric damping

- Asymmetric distribution may give higher reduction
  - ➔ case 3 Vs case 2
- Not all asymmetric distributions give higher reduction
  - ➔ case 1 Vs case 2





Summary of results from a parametric study

- Supplemental damping reduces edge deformations
  - ➔ Higher reduction with higher damping
- Degree of reduction depends on the plan-wise distribution of damping
  - ➔ Supplemental damping eccentricity (Strong)
  - ➔ Supplemental damping radius of gyration (Weak)

Quadratic eigen-value problem (State-Space formulation)

$$(\mathbf{B} + \lambda\, \mathbf{A})\, \Phi = \mathbf{0}$$

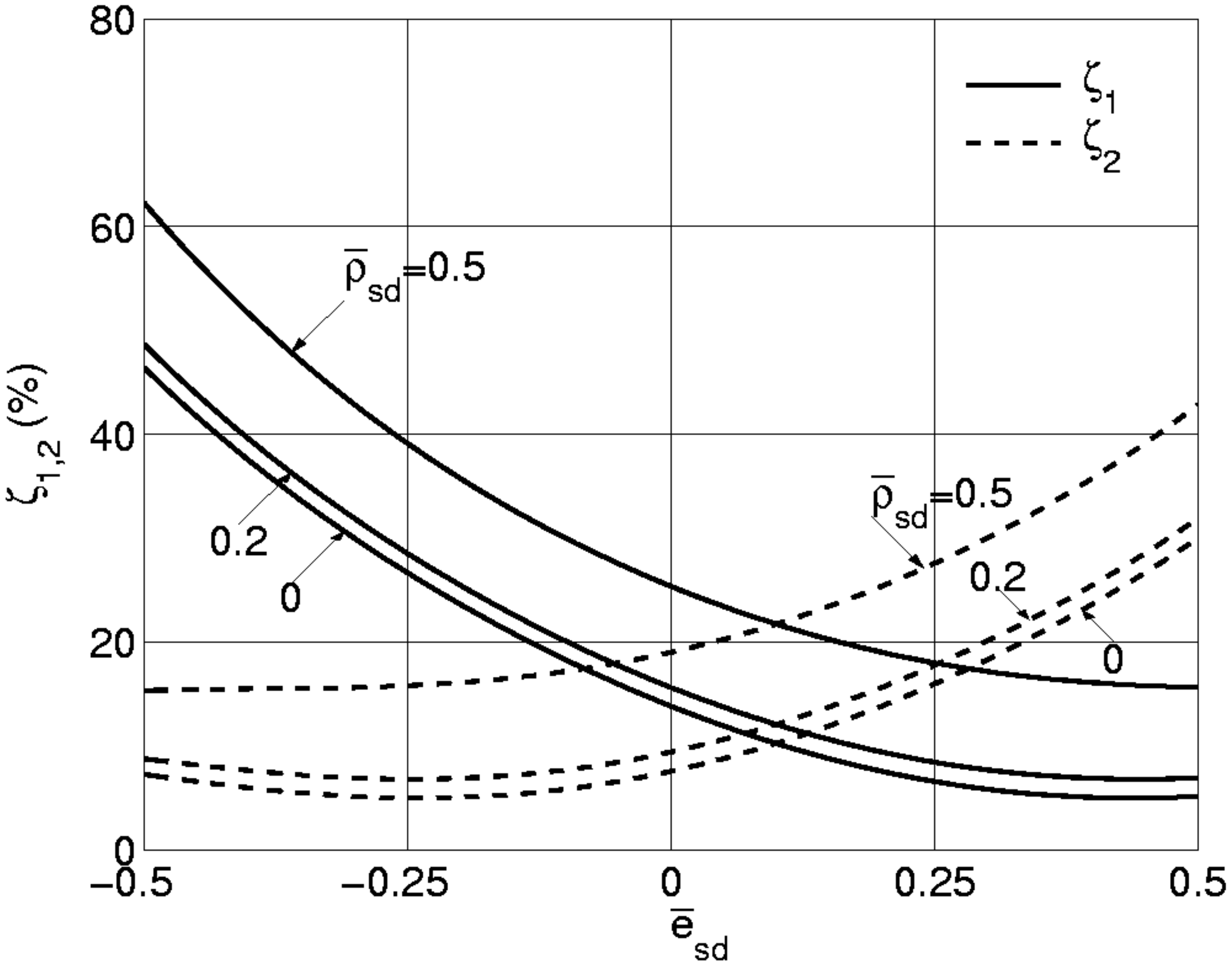
$$\mathbf{A} = \begin{bmatrix} -\mathbf{K} & \mathbf{0} \\ \mathbf{0} & \mathbf{M} \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} -\mathbf{0} & \mathbf{K} \\ \mathbf{K} & \mathbf{C} \end{bmatrix}$$

$$\lambda_n = \zeta_n \omega_n \mp j\omega_n \sqrt{1-\zeta_n^2}$$

$$\zeta_n = \text{Apparent Modal Damping}$$

$$\omega_n = \text{Apparent Modal Frequency}$$

Variation of apparent modal damping



Steady-state response to harmonic loading

$$z_{kn} = \frac{2\mathrm{R}_{\mathrm{dn}}}{\omega_{\mathrm{n}}} C_{kn} \Gamma_{\mathrm{n}} \Phi_{kn} \ddot{u}_{go}$$

$$R_{dn} = \text{Dynamic Response (Amplification Factor)}$$

$$\Gamma_n = \text{Modal Participation Factor}$$

$$\Phi_{kn} = \text{Mode Shape Component}$$

$$C_{kn} = \text{Constant Depending on Phase Angles}$$

Effect of supplemental damping distribution

- Quantities not affected significantly

$$\Gamma_n = \text{Modal Participation Factor}$$

$$\Phi_{kn} = \text{Mode Shape Component}$$

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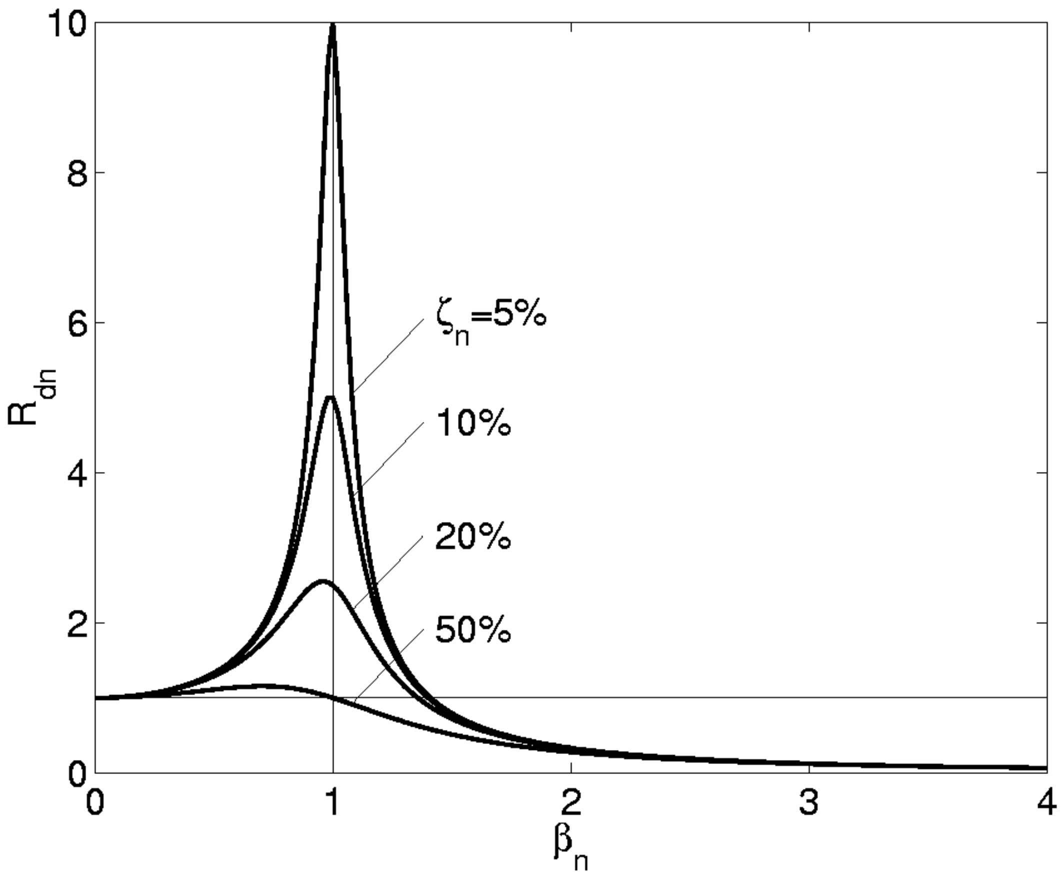
$$\omega_n = \text{Apparent Modal Frequency}$$

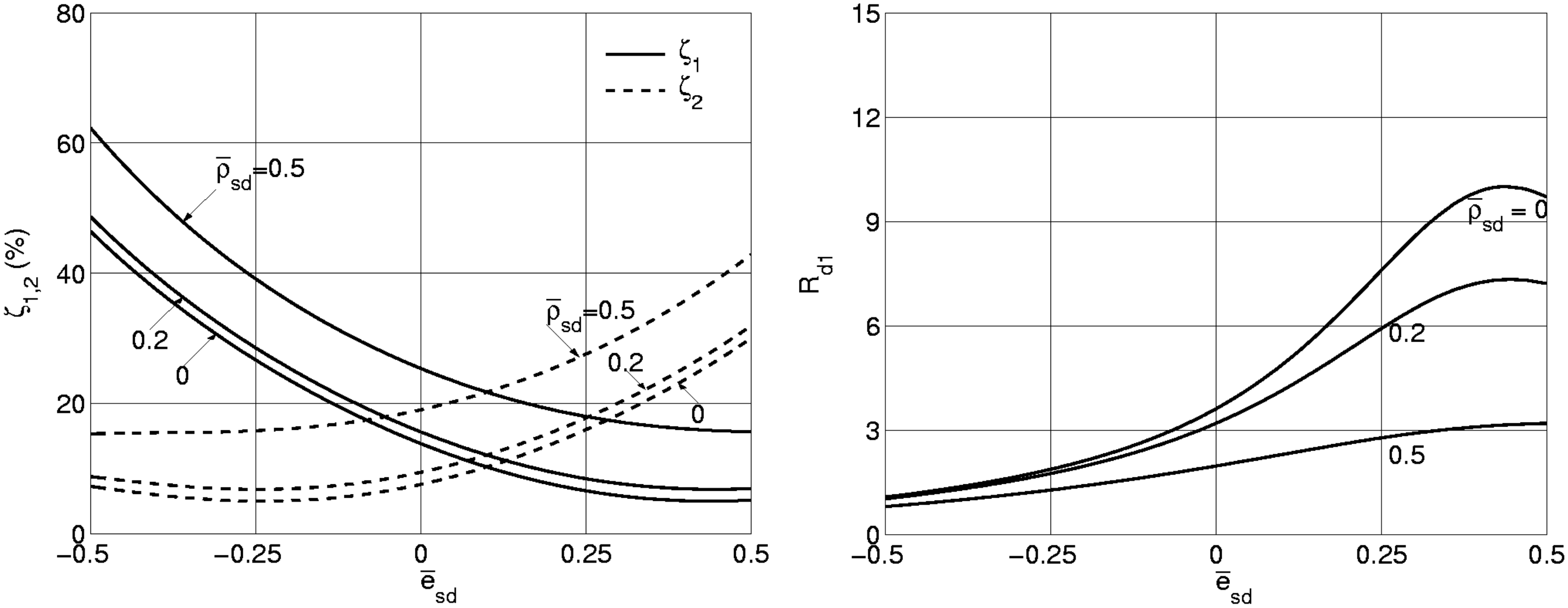
- Quantity affected significantly

$$R_{dn} = \text{Dynamic Response (Amplification Factor)}$$

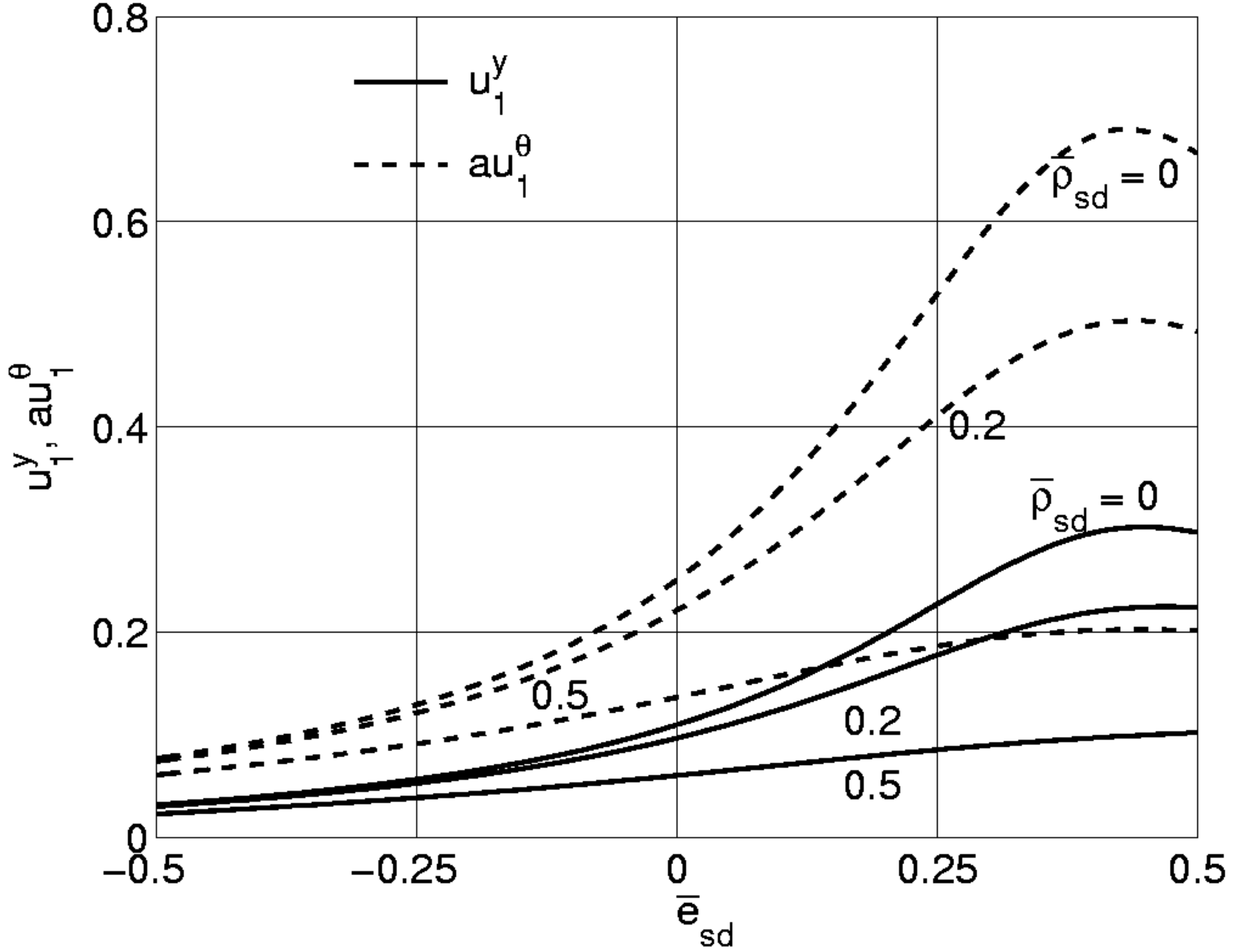
Variation of dynamic response factor with damping



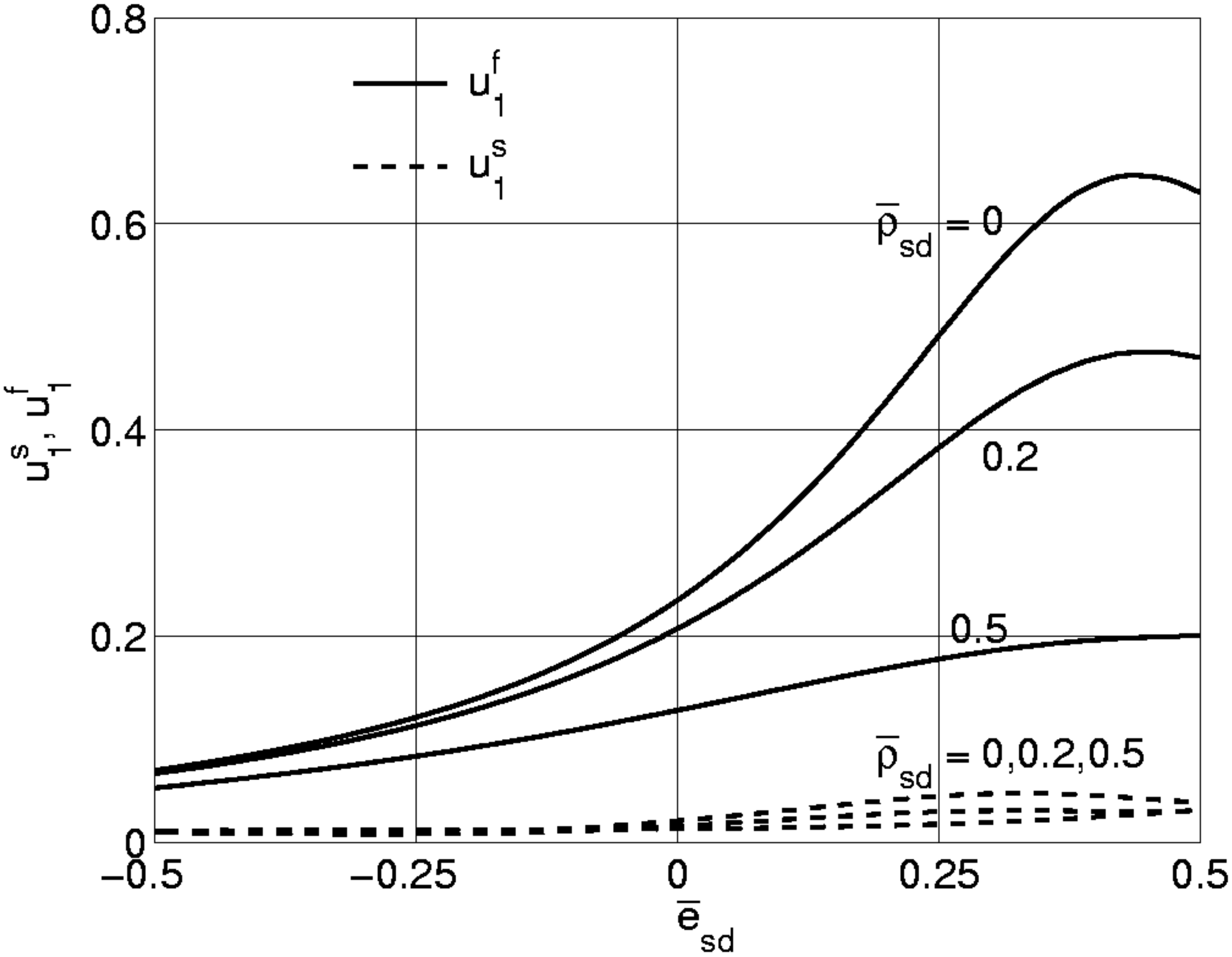
Effect of apparent modal damping on R_{dn} ($\beta_1 = \omega/\omega_1 = 1$)



Variation of deformations at CM



Variation of edge deformation



Conclusions

- Larger reduction with asymmetric distribution of supplemental damping
- CSD on opposite side of CM as CR for controlling deformations (at CM as well as at edges)
- Apparent modal damping is the key parameter that controls the response
  - ➔Simplified procedures should be able to correctly capture the apparent modal damping