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Seismic Demands and their Dependence on Ground Motions

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2001 PEER Annual Meeting

What are Seismic Demands?

- **Damage Measures**
  - Roof and story drifts
  - Local deformations (e.g., plastic hinge rotation)
  - Floor acceleration and velocity
  - Cost-related damage indices
  - Cumulative damage measures (e.g., energy)
- **Design Parameters**
  - Story shear forces and overturning moments
  - Relative strength of fuses (strong column concept)

Purpose of Demand Evaluation

- Understanding of Behavior
- Rigorous Probabilistic Performance Assessment in the Presence of Uncertainties
- Approximate Performance Assessment
- Conceptual Design (Strength and Stiffness Requirements)

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Probabilistic Performance Assessment in the Presence of Uncertainties

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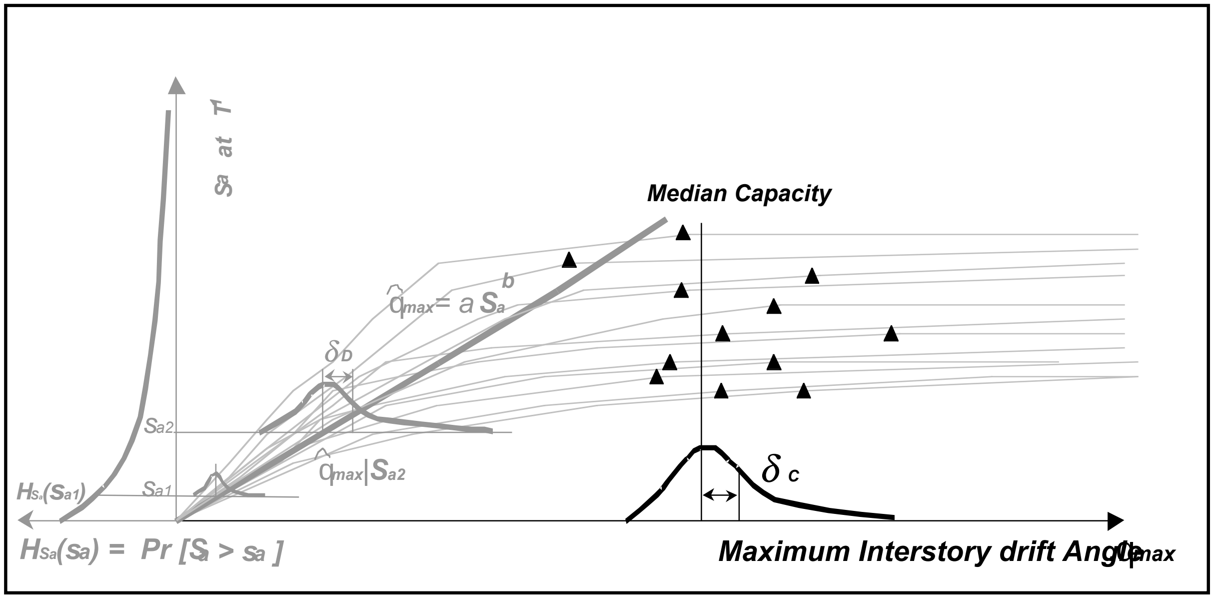
Incremental Dynamic Analysis (IDA)



- *Spectral Acceleration Hazard*
- *Incremental Dynamic Analysis Curves*
- *Probability Distribution of Drift given S_a*
- ***System Drift Capacity Data Points***
- ***Probability Distribution of Capacity***

Cornell/Jalayer

Accuracy of IDA Depends on

- **Description of return period dependent hazard**
  - Intensity measure
  - Frequency content
  - Duration
- **Description of structural properties, including deterioration**
- **Analytical modeling and analysis tool**
- **Method of prediction (analysis method)**

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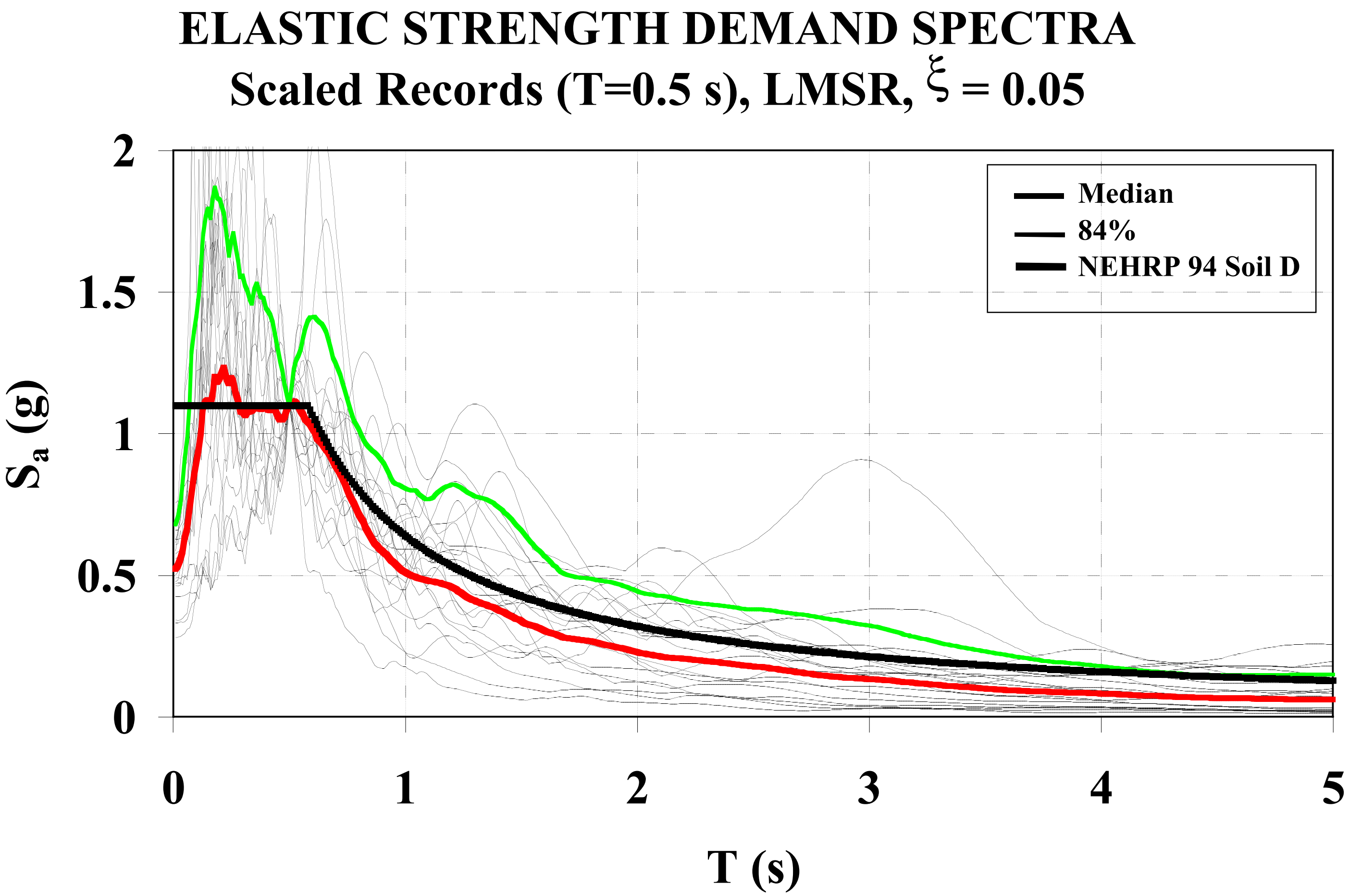
Description of return period dependent hazard

Frequency Effects, T_1 = 0.5 sec.



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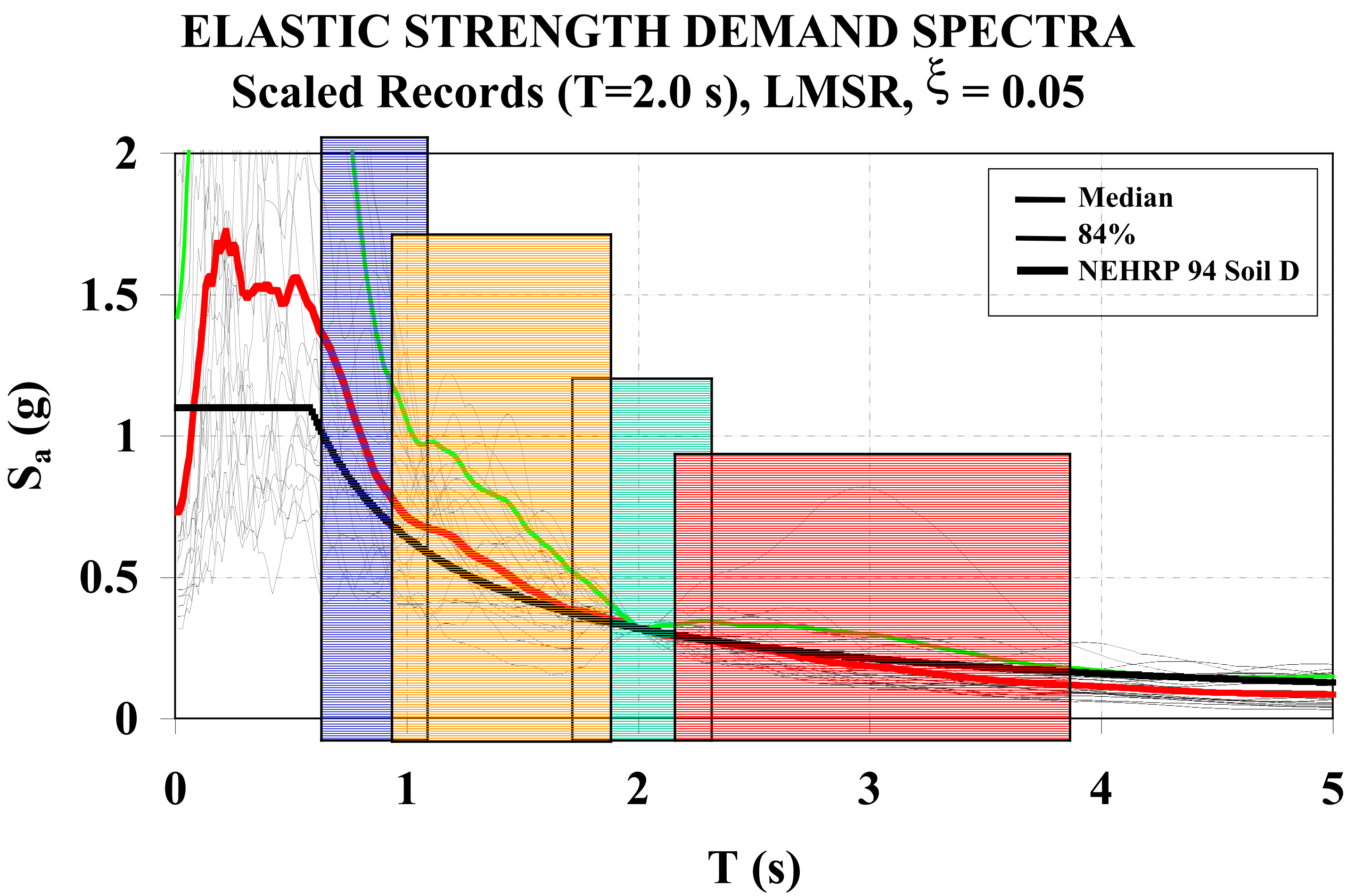
Frequency Effects, T_1 = 2.0 sec.



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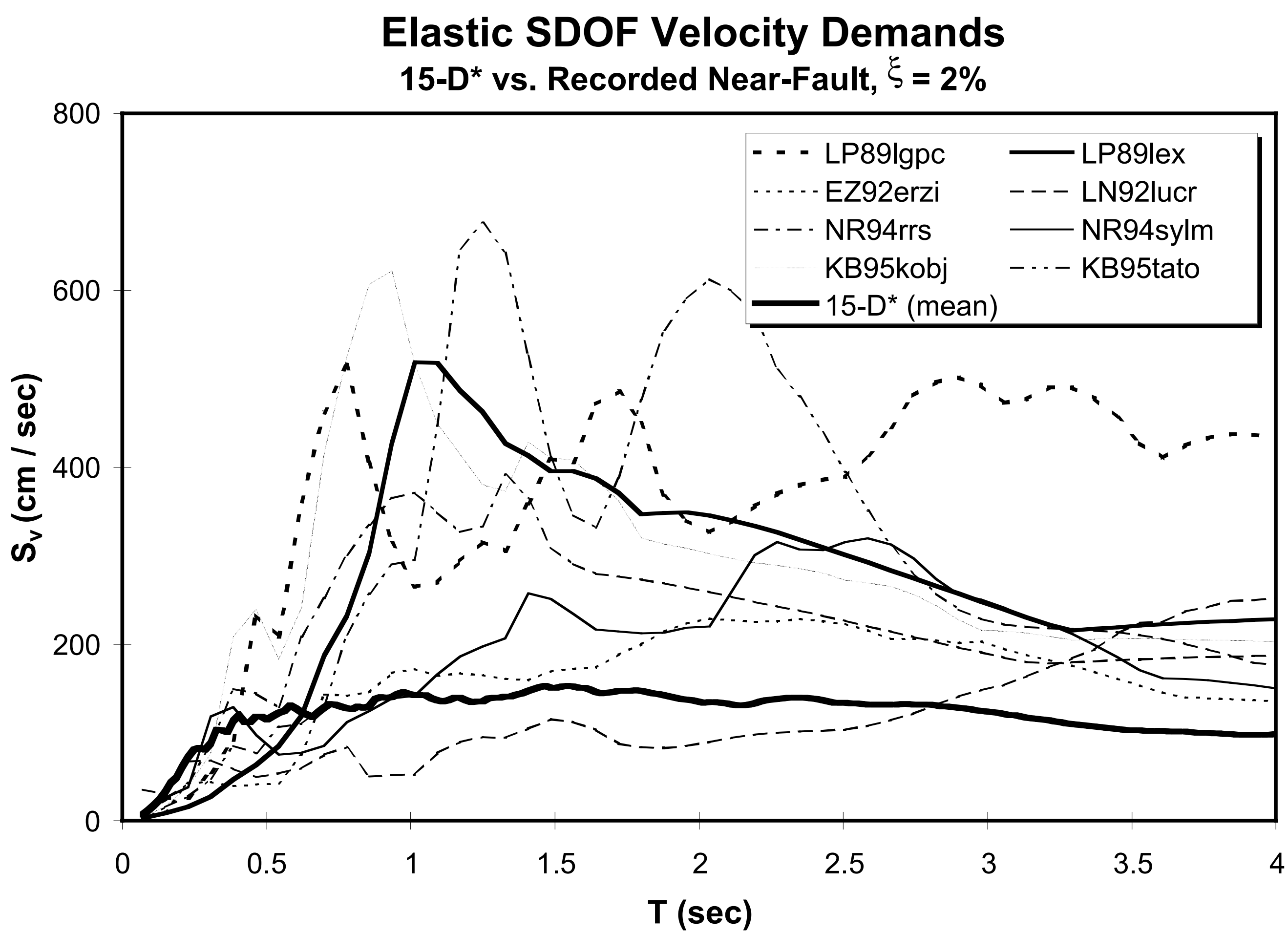
Near-Fault Effects



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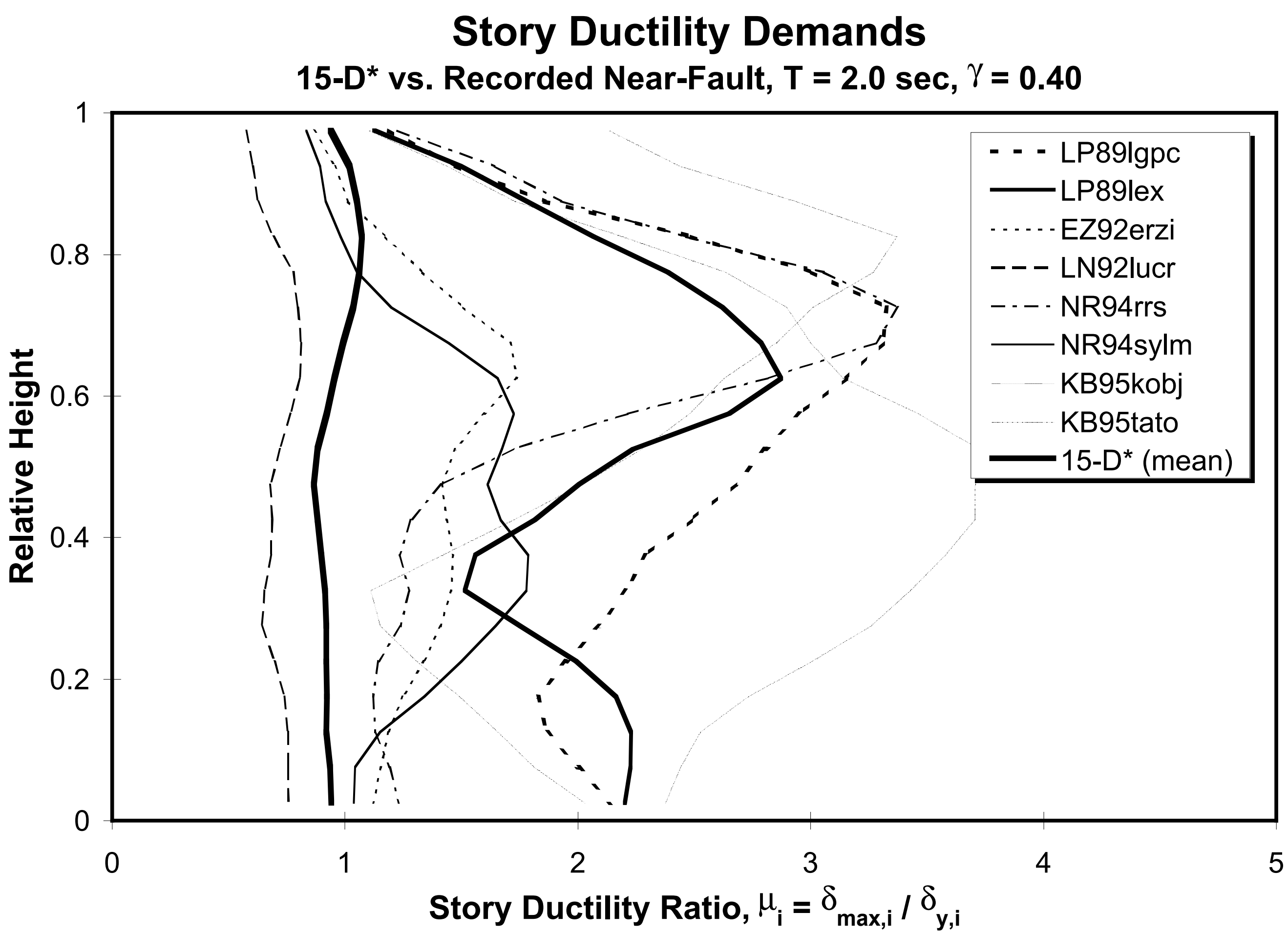
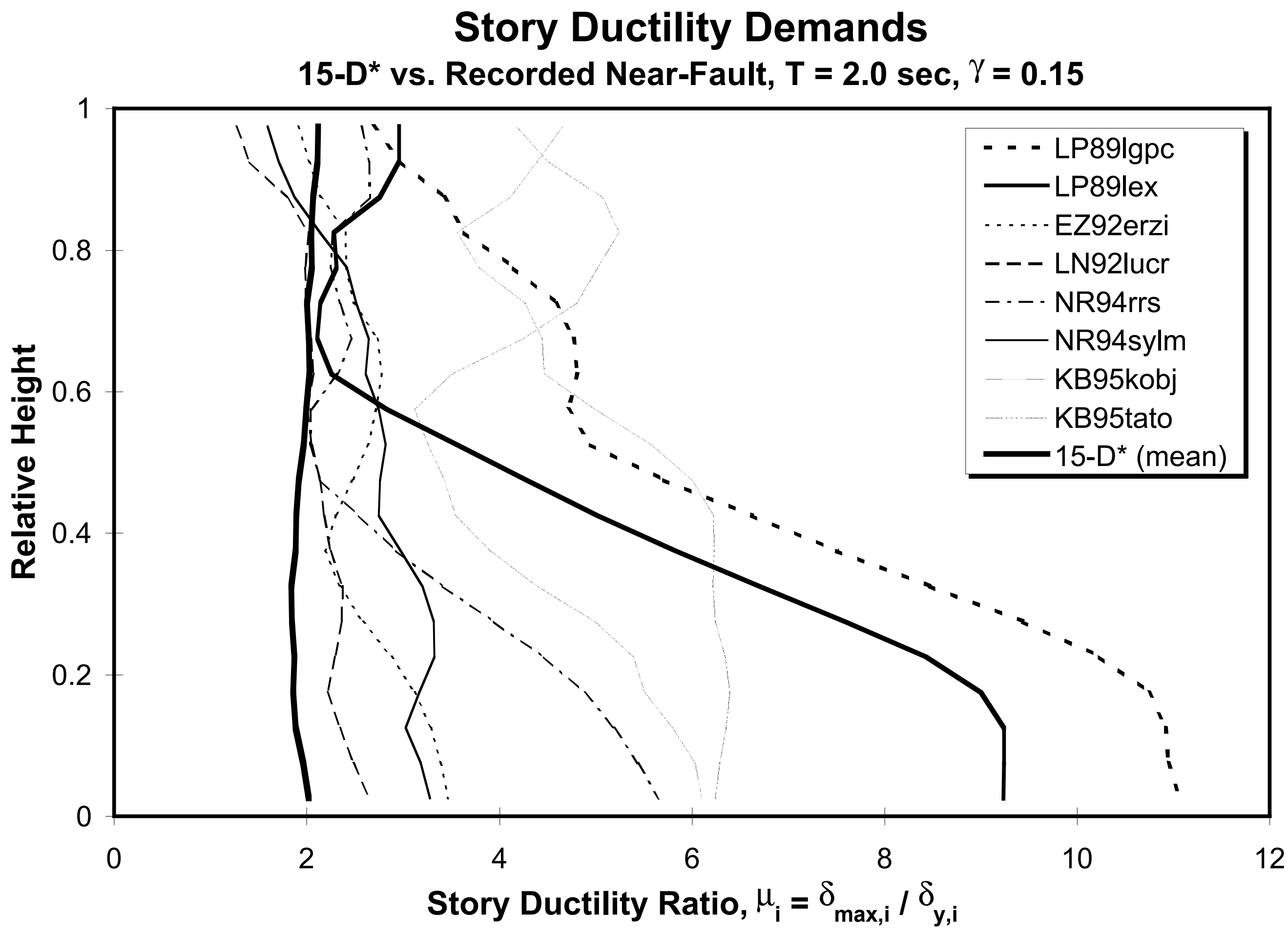
NF Response of Strong Structures



NF Response of Weak Structures



Improvement of Intensity Measure

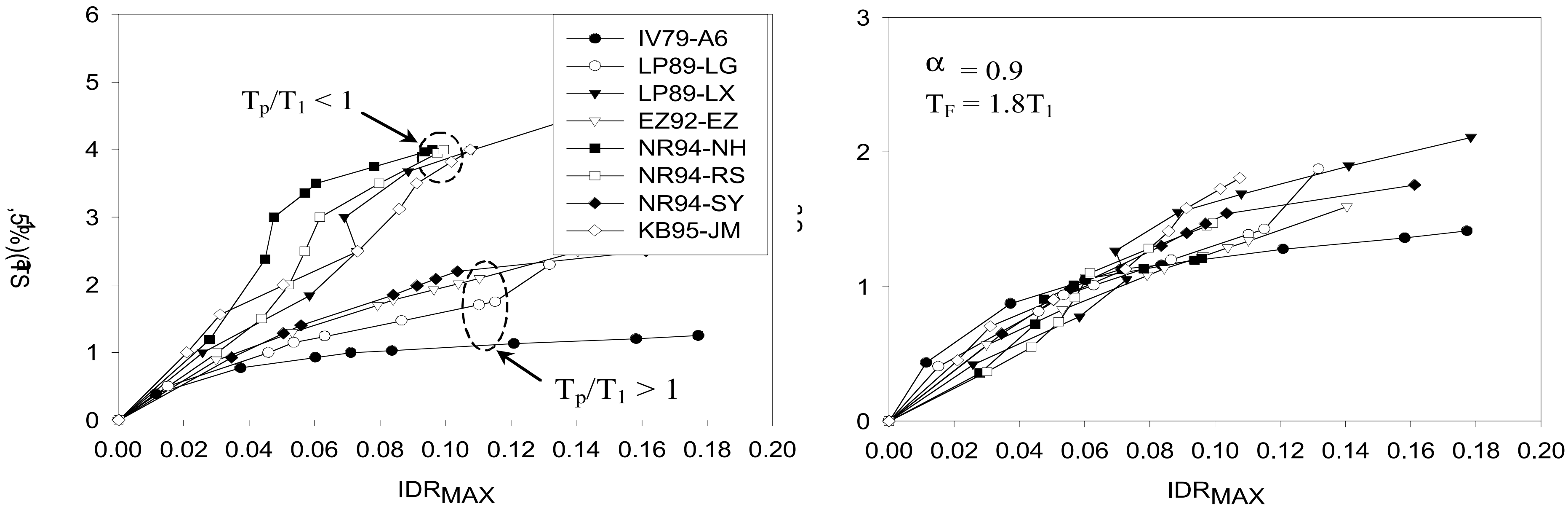


Figure 5 – IDA plot of IDR versus (left) $S_a(T_1)$ and (right) $S_aR_{sa}^{\alpha}$

(a) Intensity Measure = $S_a(T_1)$

(b) Intensity Measure = $S_aR_{sa}^{\alpha}$

Cordova/Deierlein

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Description of structural properties, including deterioration

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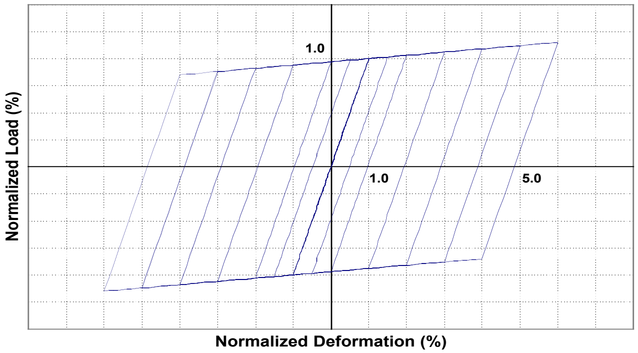
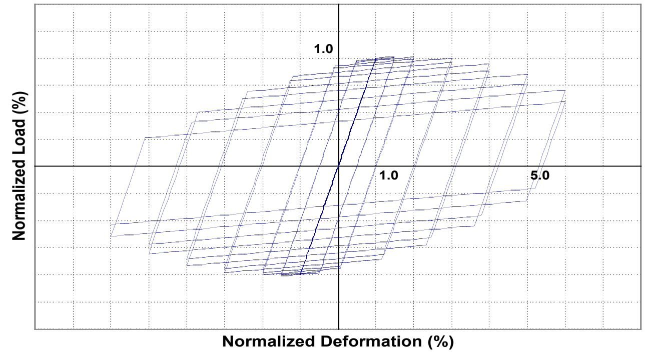
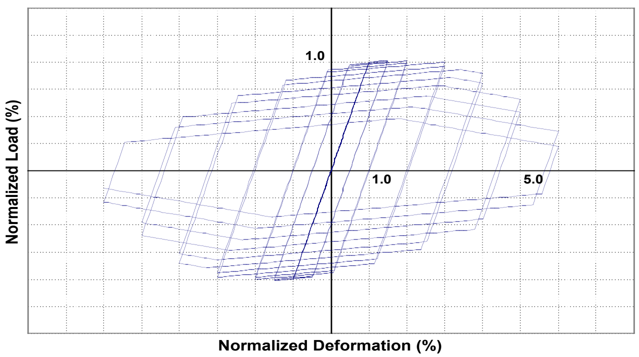
Basic Modes of Deterioration



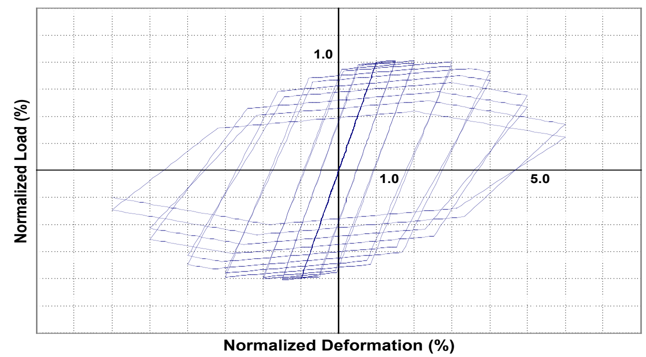
No deterioration



Strength deterioration

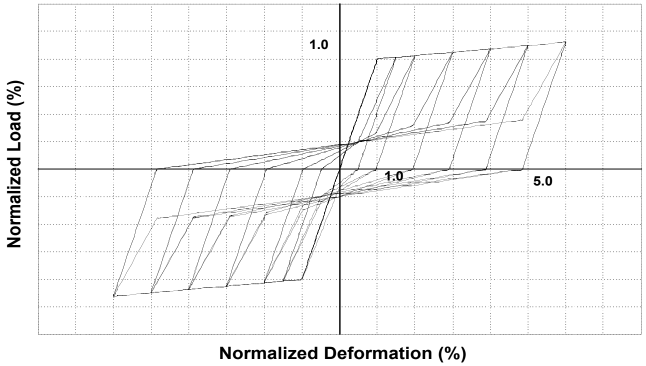


Strength det. with capping

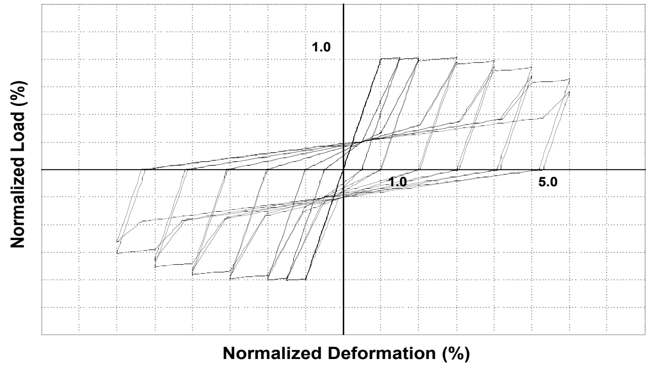


Strength det. with capping & stiff. det

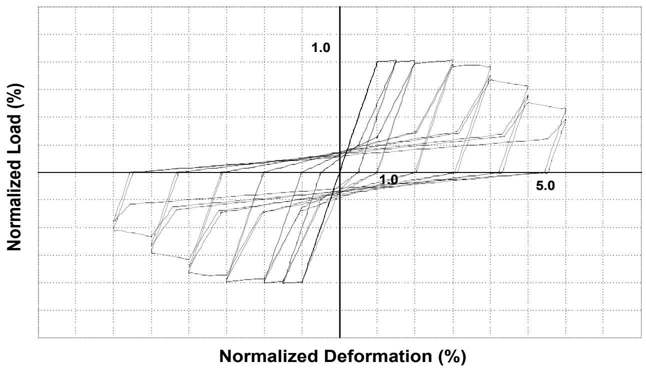
Det. Modes for Pinching System



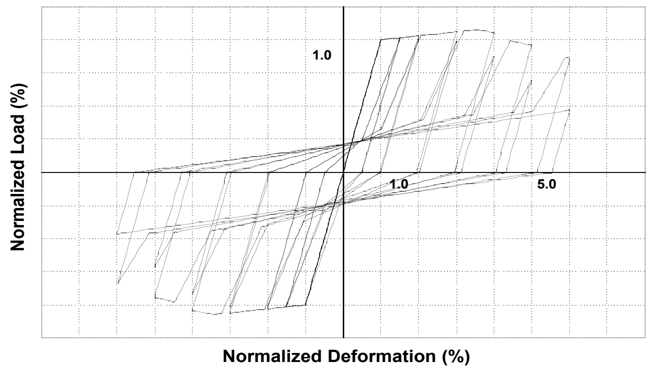
No deterioration



Strength deterioration



Strength det. with capping



Accelerated stiffness det. with capping

Example of Deterioration Model

A single deterioration parameter:

$$\beta_i = \left(\frac{E_i}{E_t - \sum_{j=1}^{i} E_j} \right)^c$$

in which β_i **= parameter defining the deterioration in excursion** i

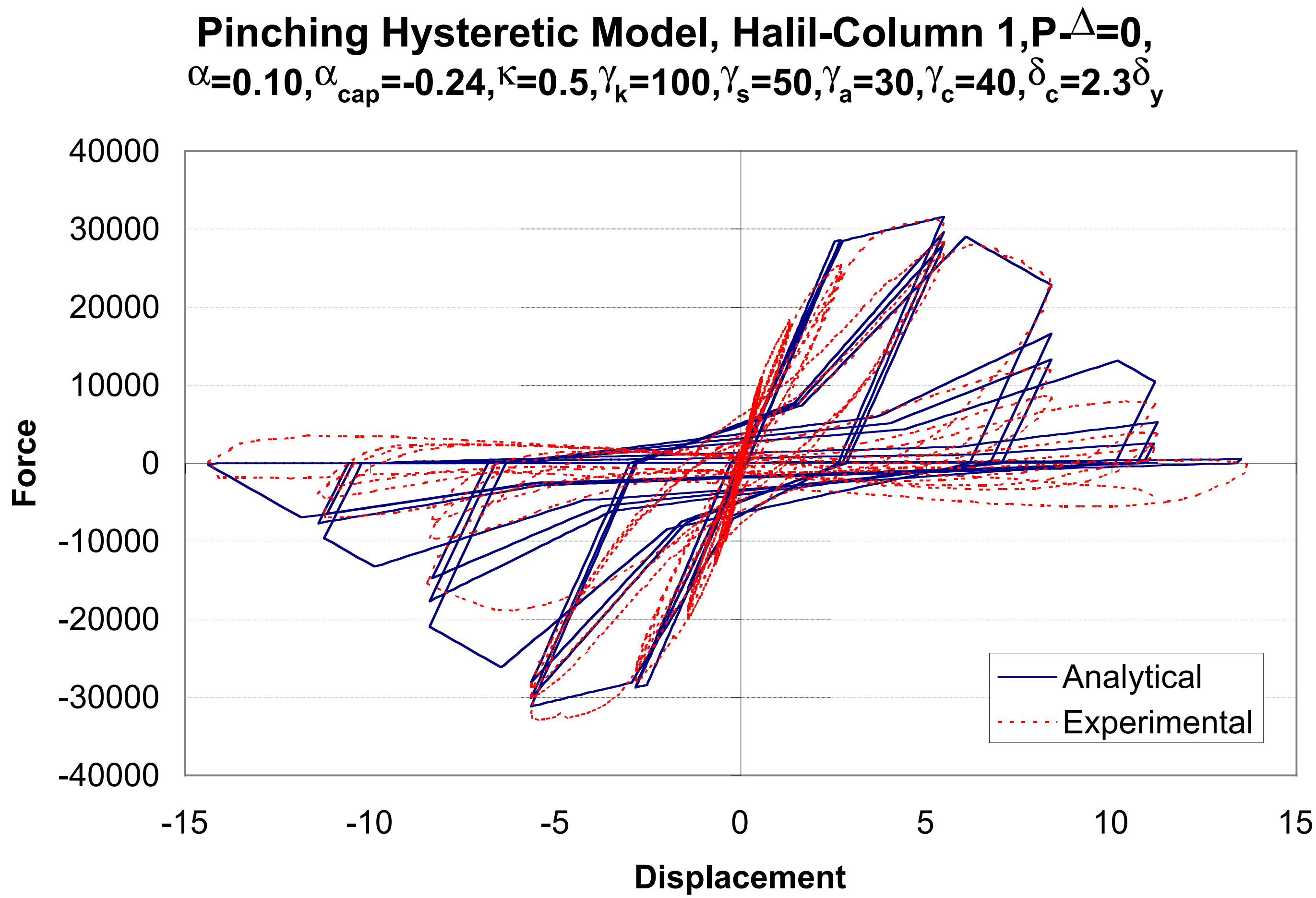
E_i = hysteretic energy dissipated in excursion i

E_t = hysteretic energy dissipation capacity = $\gamma F_y \delta_y$

$\sum E_j$ = ηψστερετιχ ενε ργψ δισσιπατεδ ιν αλλ πρεϖιους εξχυρσιονσ

c **= exponent defining the rate of deterioration**

Calibration of Deterioration Model



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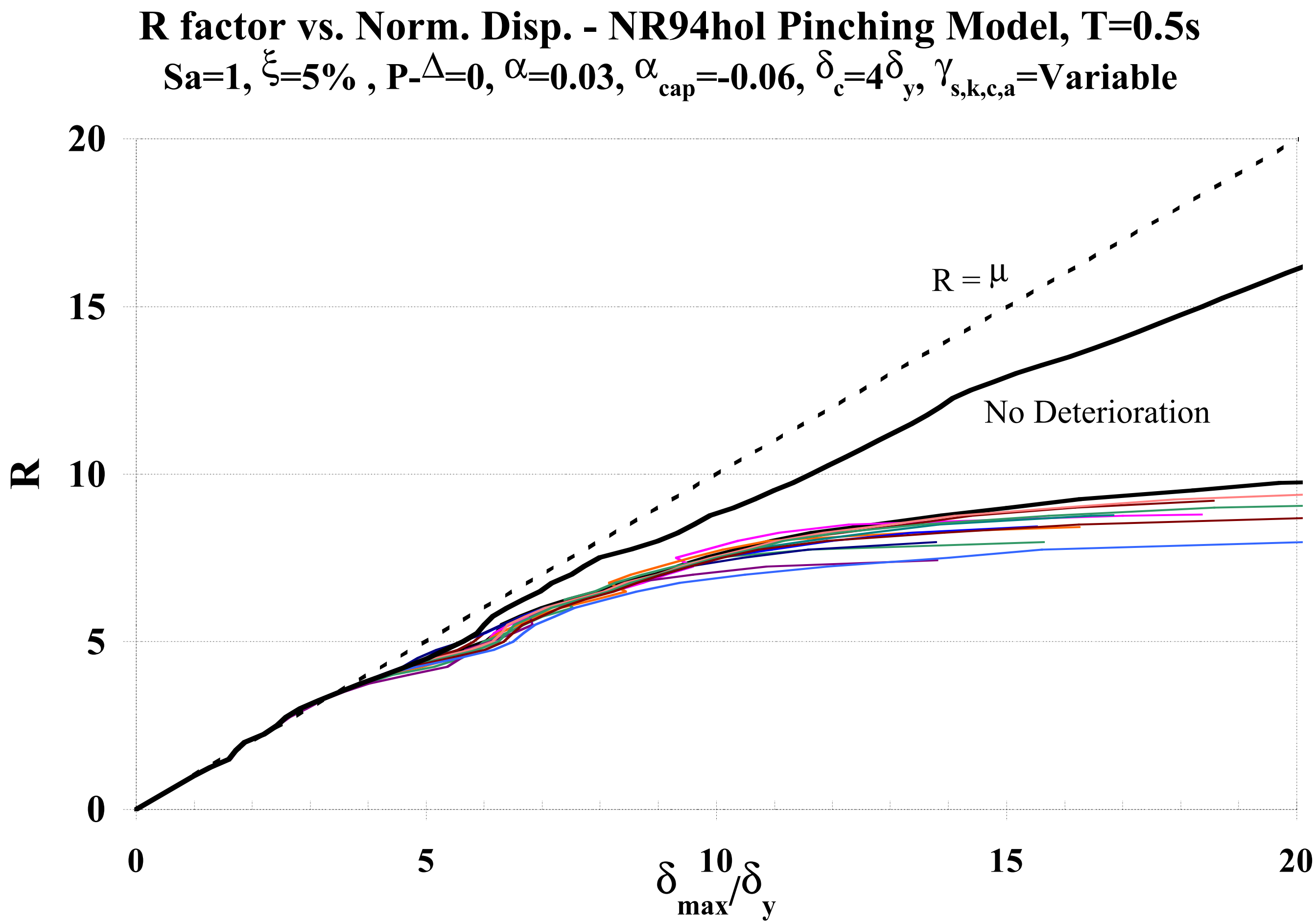
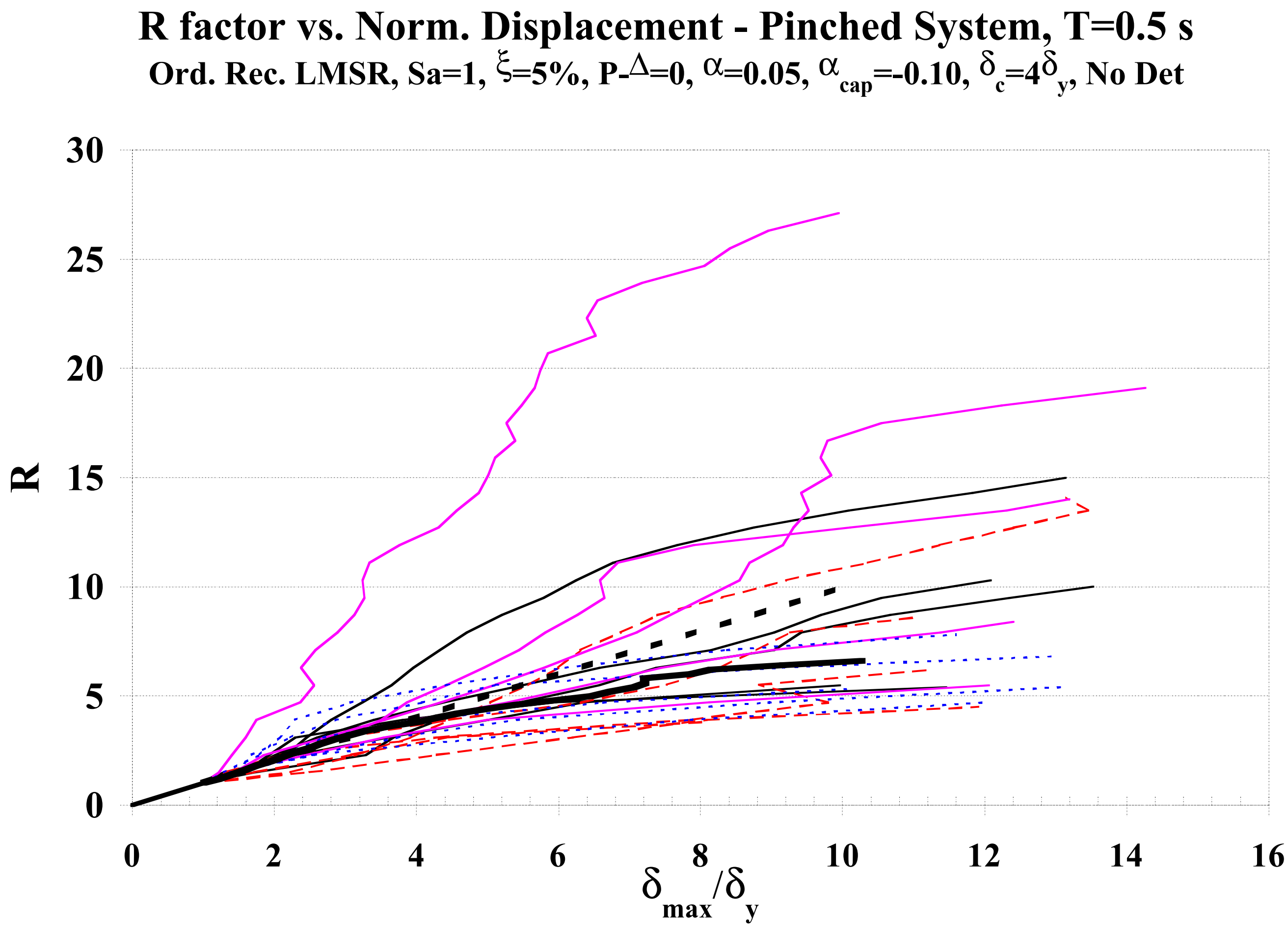
Sensitivity to Deterioration, SDOF



Sensitivity to Frequency Content



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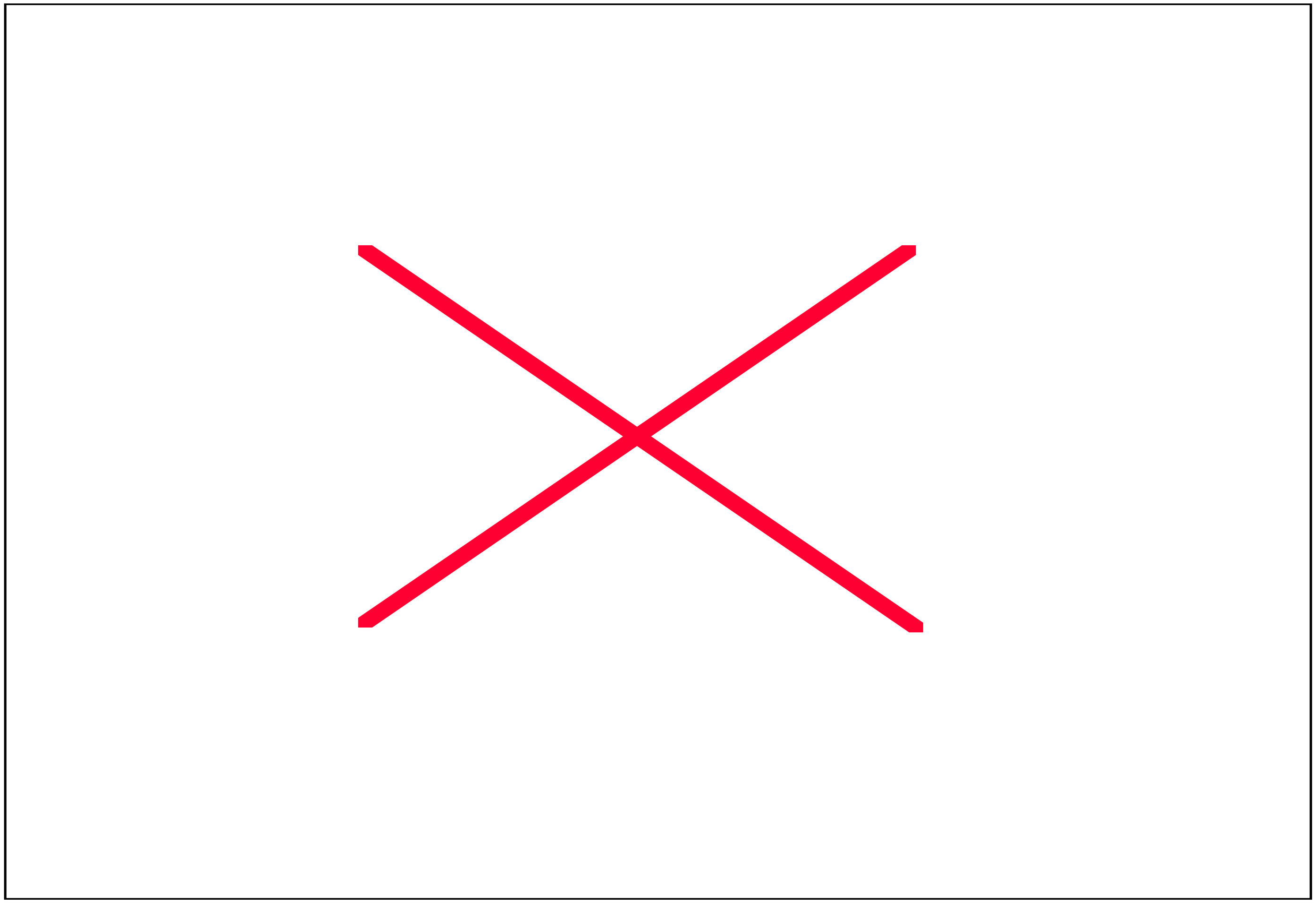
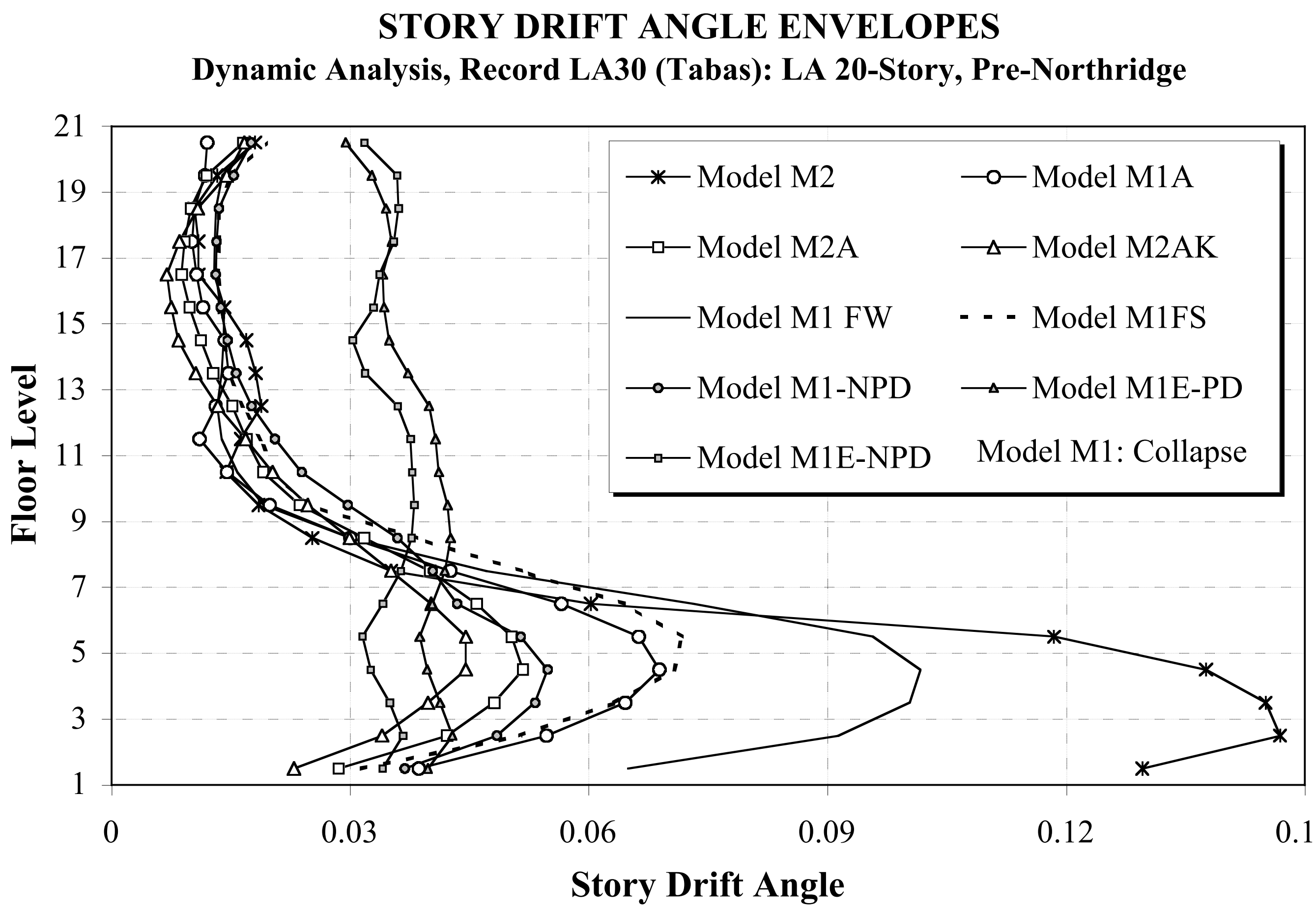
Deterioration Effect, MDOF System



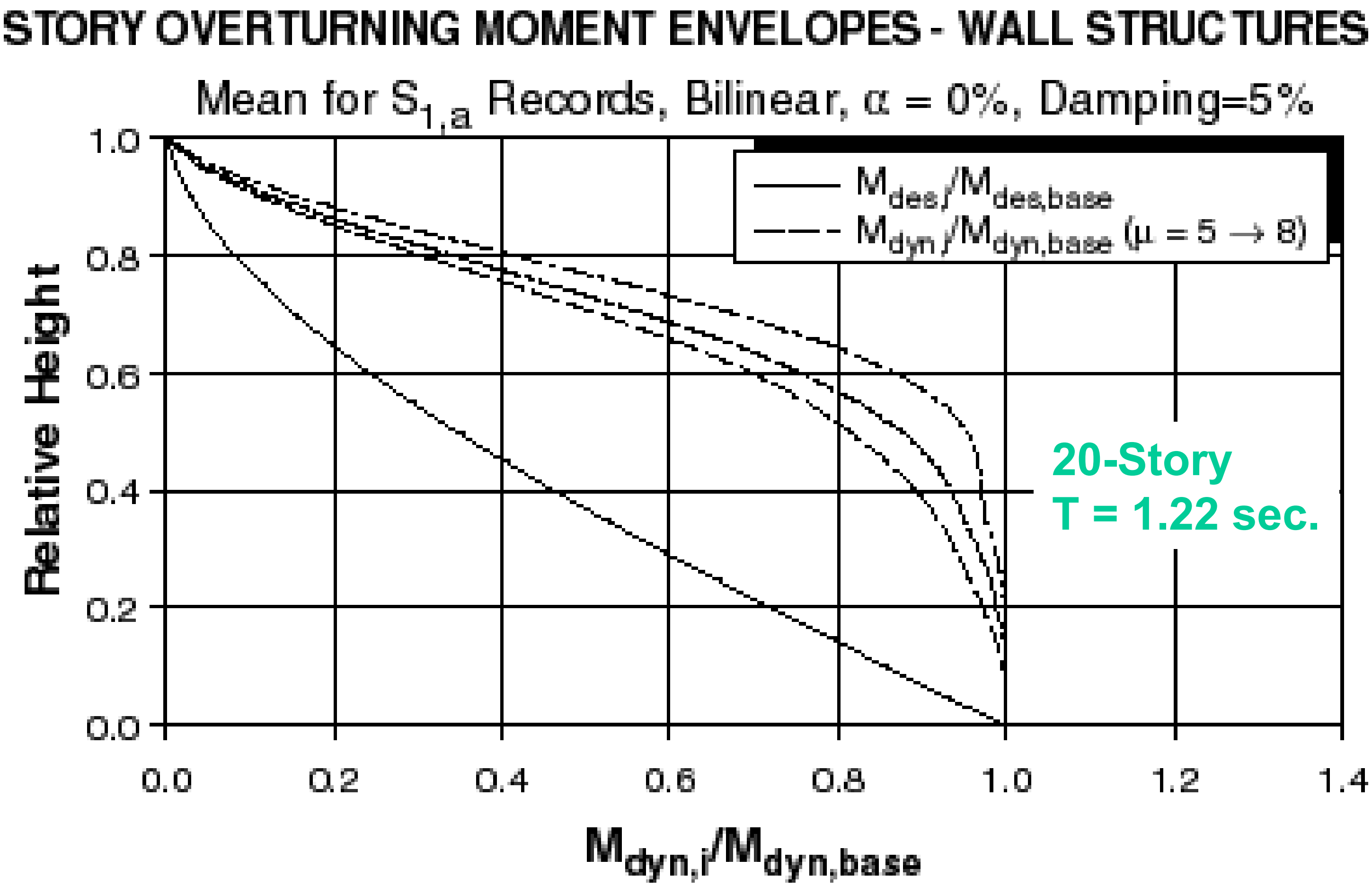
Analytical Modeling and Analysis Tool

- **Incorporate deterioration models**
- **Incorporate uncertainty in properties**
- **Soil-foundation-structure interaction**
- **Modeling of 3-D effects**

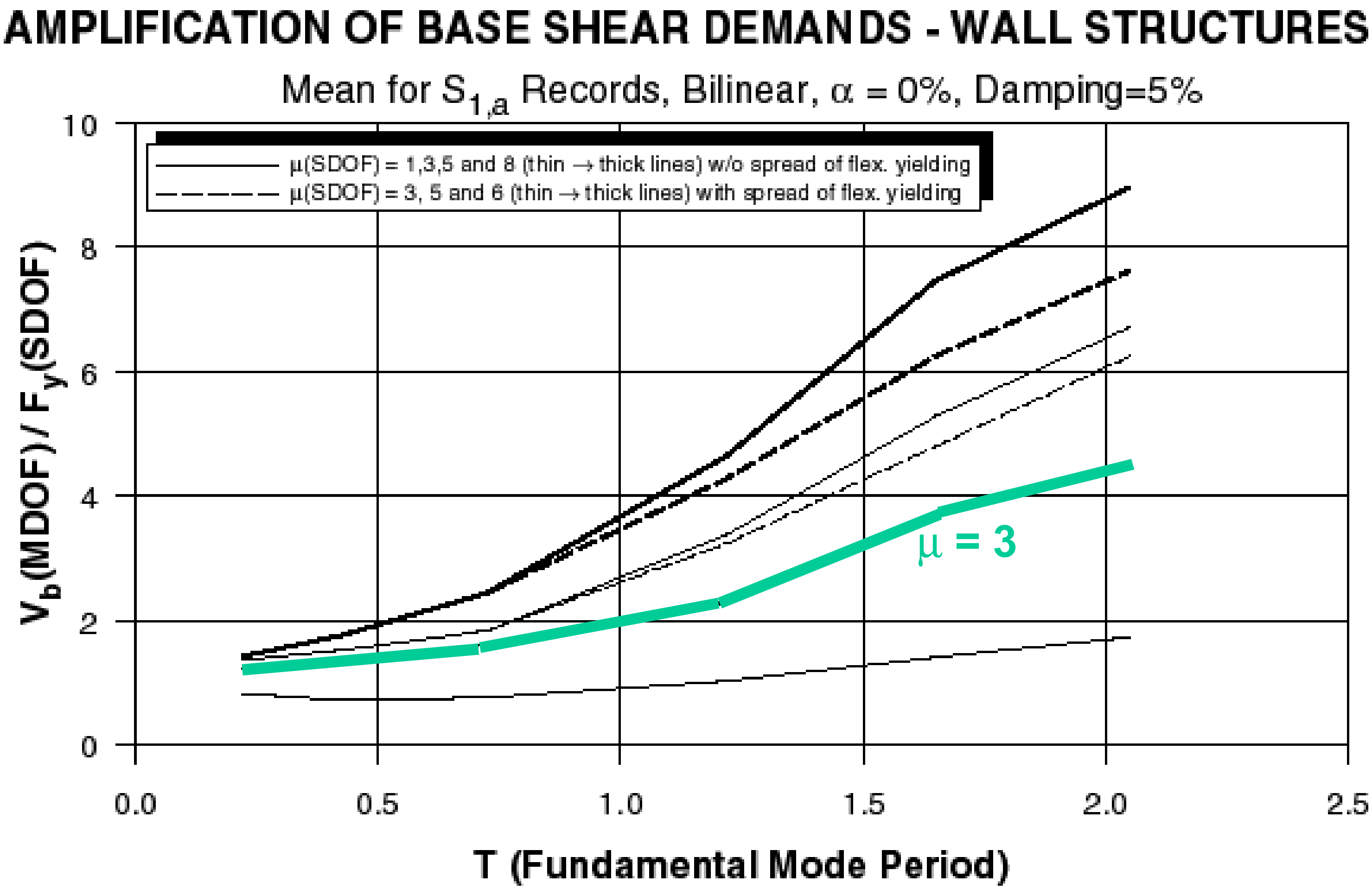
Method of Prediction (Analysis Method)



Understanding of Behavior - Walls



Understanding of Behavior - Walls



PEER Research Activities

- Demand database for many structural systems and different ground motion types
- Sensitivity of demands to ground motion characteristics (ordinary and near-fault)
- Collapse safety prediction from IDAs
- Improved intensity measures for reducing uncertainties in demand prediction
- Prediction of demand parameters for loss estimation (structural and nonstructural)

PEER Research Activities, cont'd

- Modeling of deterioration
- Evaluation of demand parameters for conceptual design
- Fragility curves for bridge peers and systems
- Probabilistic demand models for bridges

Ultimate Objective

- Provide knowledge and data needed to implement a performance assessment methodology based on the PEER framework equation (short term)
- Provide understanding, knowledge, and data needed to develop and implement a performance-based conceptual design methodology for retrofitting existing structures and designing new ones (long range)