PEER Bridge Case Studies

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Outline

- Probabilistic vs. deterministic briefly
- PEER bridge case studies
  - Early days of PEER
  - I-880 testbed
  - Humboldt Bay Bridge testbed
- Recent PEER testbed and model
- Nonlinear vs. Linear analysis
  - Advantages
  - Disadvantages
- Bridge fragilities
- Improvements

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Deterministic vs. Probabilistic Analysis

- Deterministic linear
  - Linear modal response-spectrum analysis
- Deterministic nonlinear
  - Nonlinear static pushover procedures
  - N2, CSM, MPA, adaptive MPA

} No fragility data

- Probabilistic linear
  - Linear dynamic time history
    - Gross/cracked section properties
    - Secant stiffness for yielding members

} May underestimate dispersion at high intensities

- Probabilistic nonlinear
  - Nonlinear dynamic time history
    - Simplified structural models
    - Detailed structural models
    - Fully coupled soil-structure-foundation interaction models

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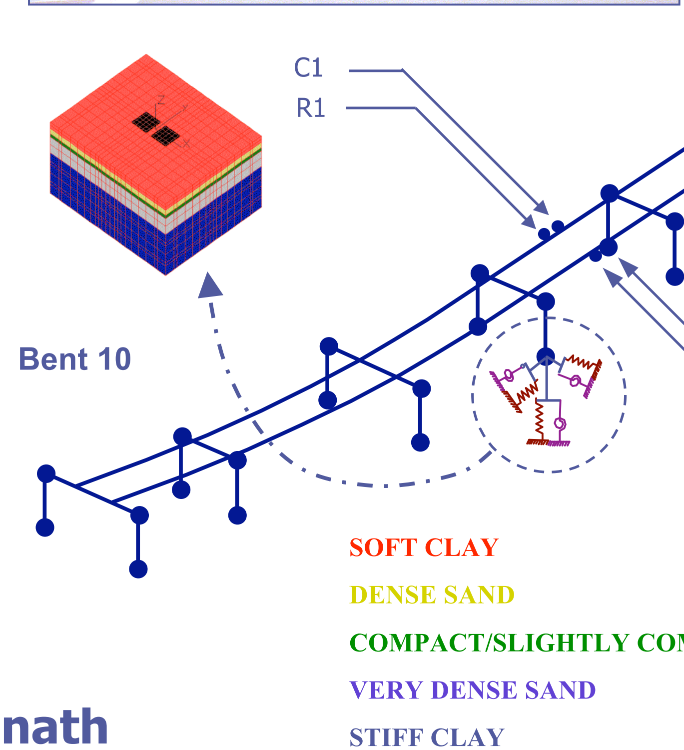
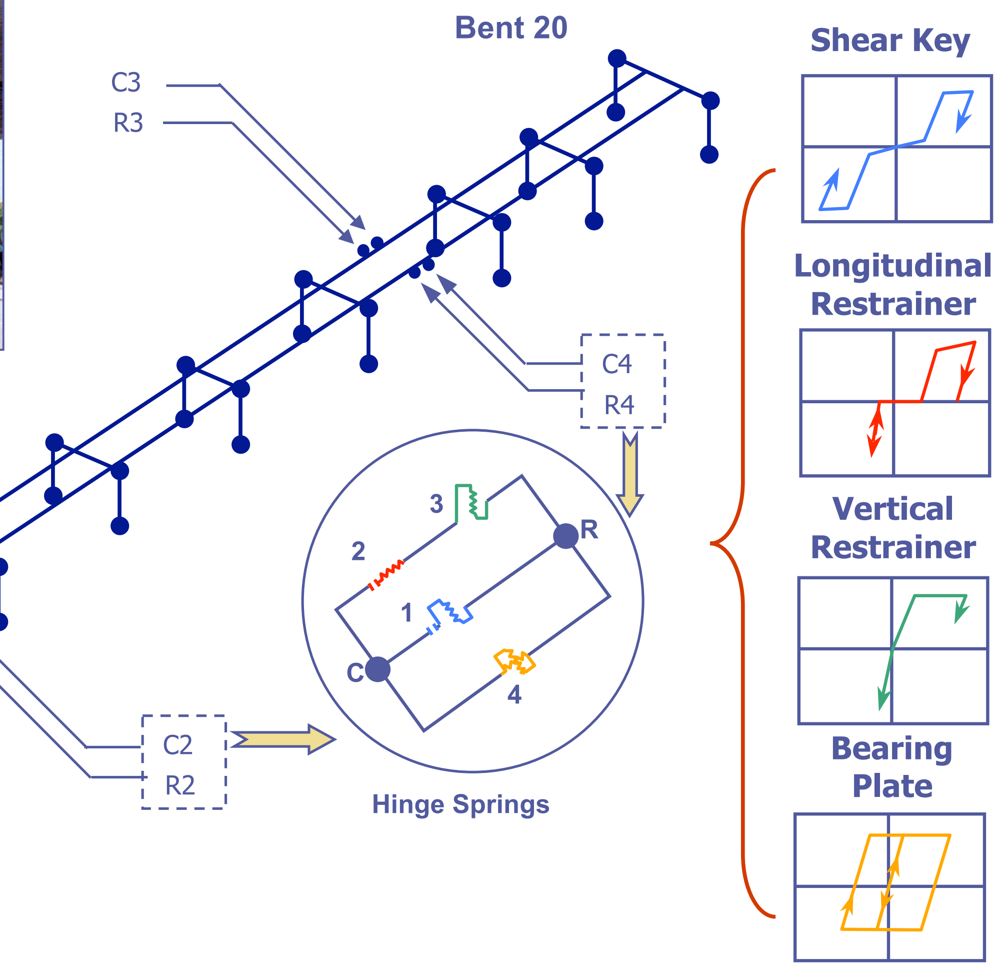
PEER Bridge Studies

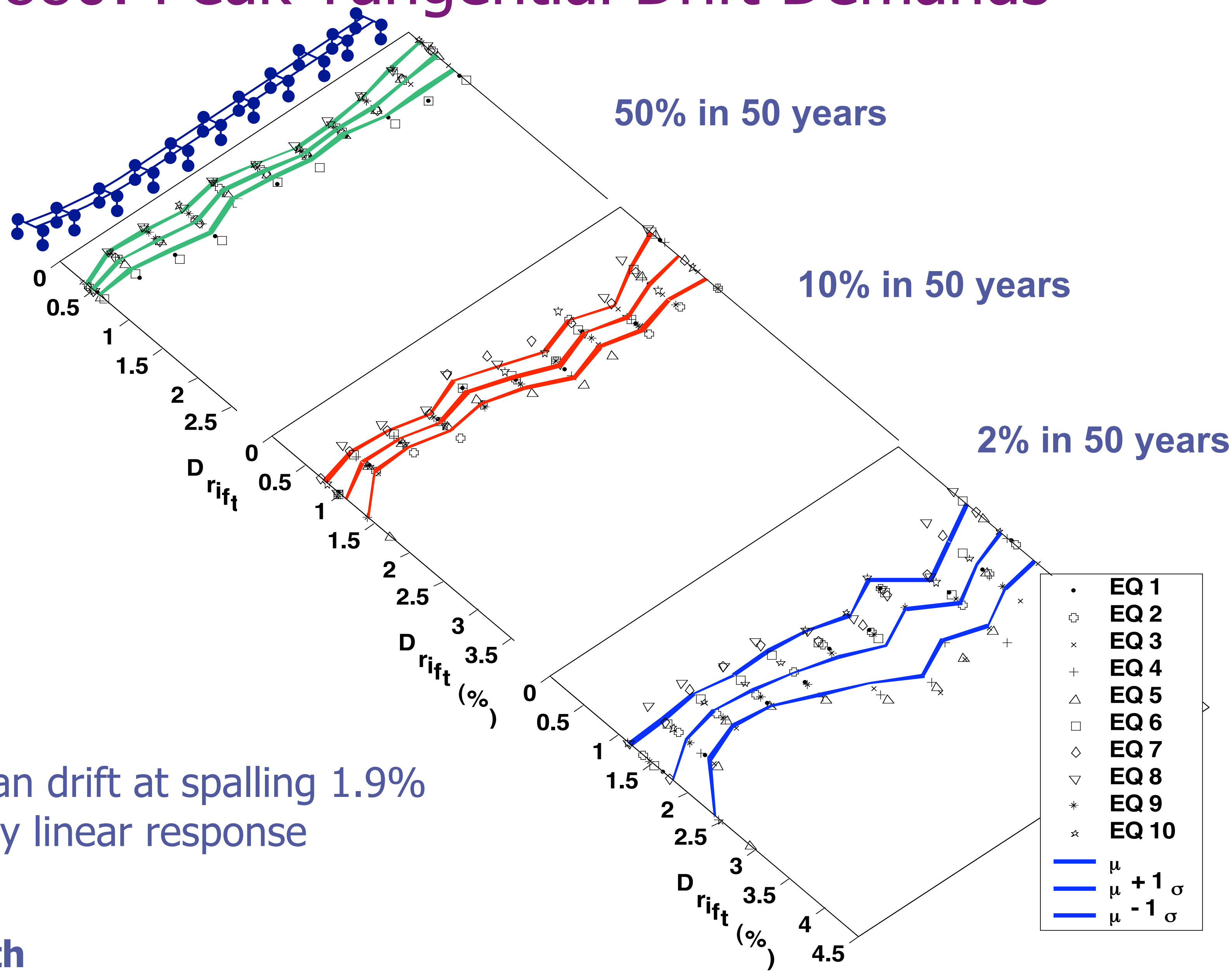
- Previous PEER bridge studies
  - PEER 312/318 research
    - Mackie/Stojadinovic, UCB
  - I-880 Testbed
    - Kunnath/Jeremic, UCD
  - Humboldt Bay Bridge Testbed
    - Conte/Elgamal, UCLA/UCSD
- Current bridge study
  - Typical Caltrans overpass Testbed
    - PEER Yr. 8-10
    - UCB, UW, etc.
    - Modular design for exchange of components
    - See poster for more details
- Rely heavily on nonlinear probabilistic analysis

I-880 Simulation Model





I-880: Peak Tangential Drift Demands



Median drift at spalling 1.9%
Mostly linear response

Kunnath

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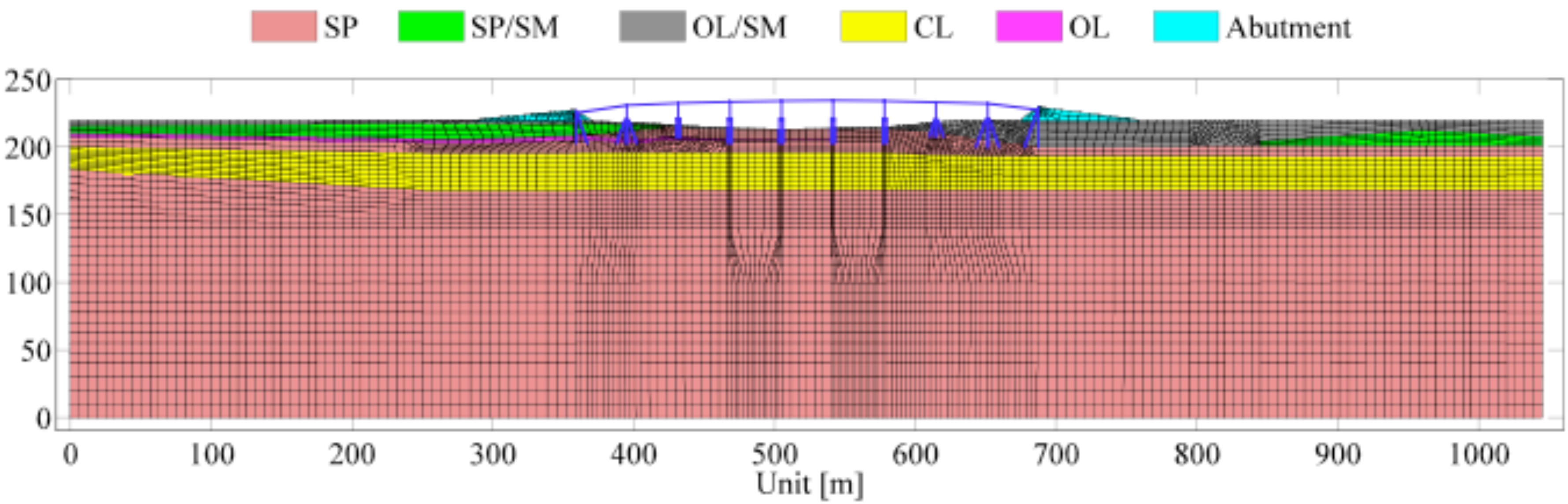
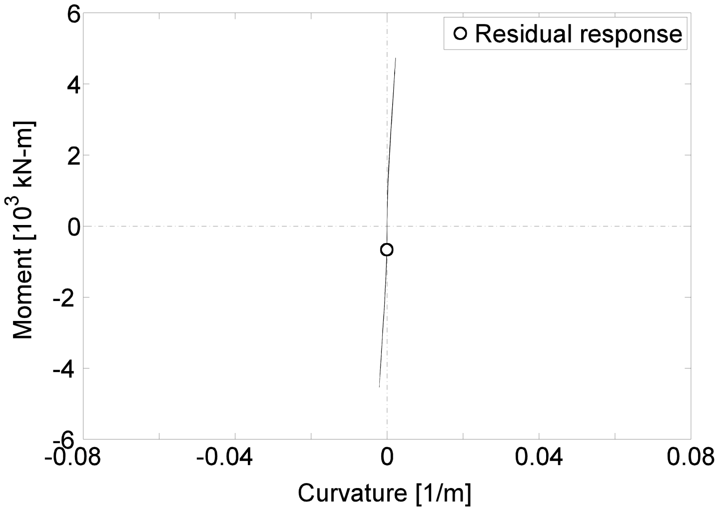
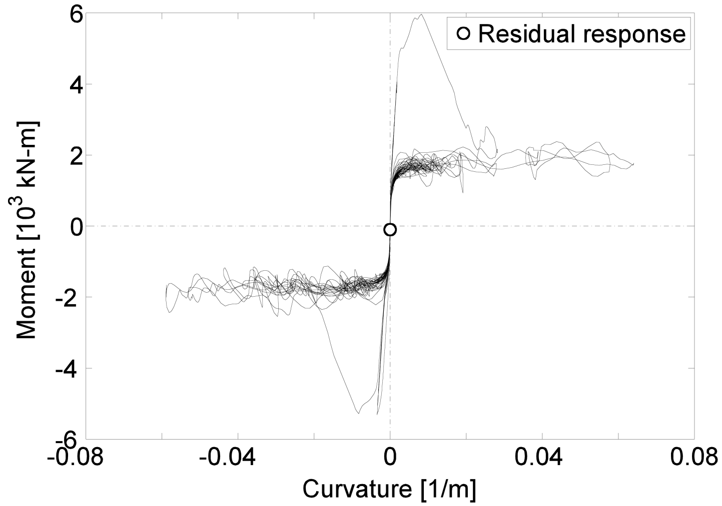
Humboldt Bay Bridge



HBB: Moment-Curvature, Pier #3 base



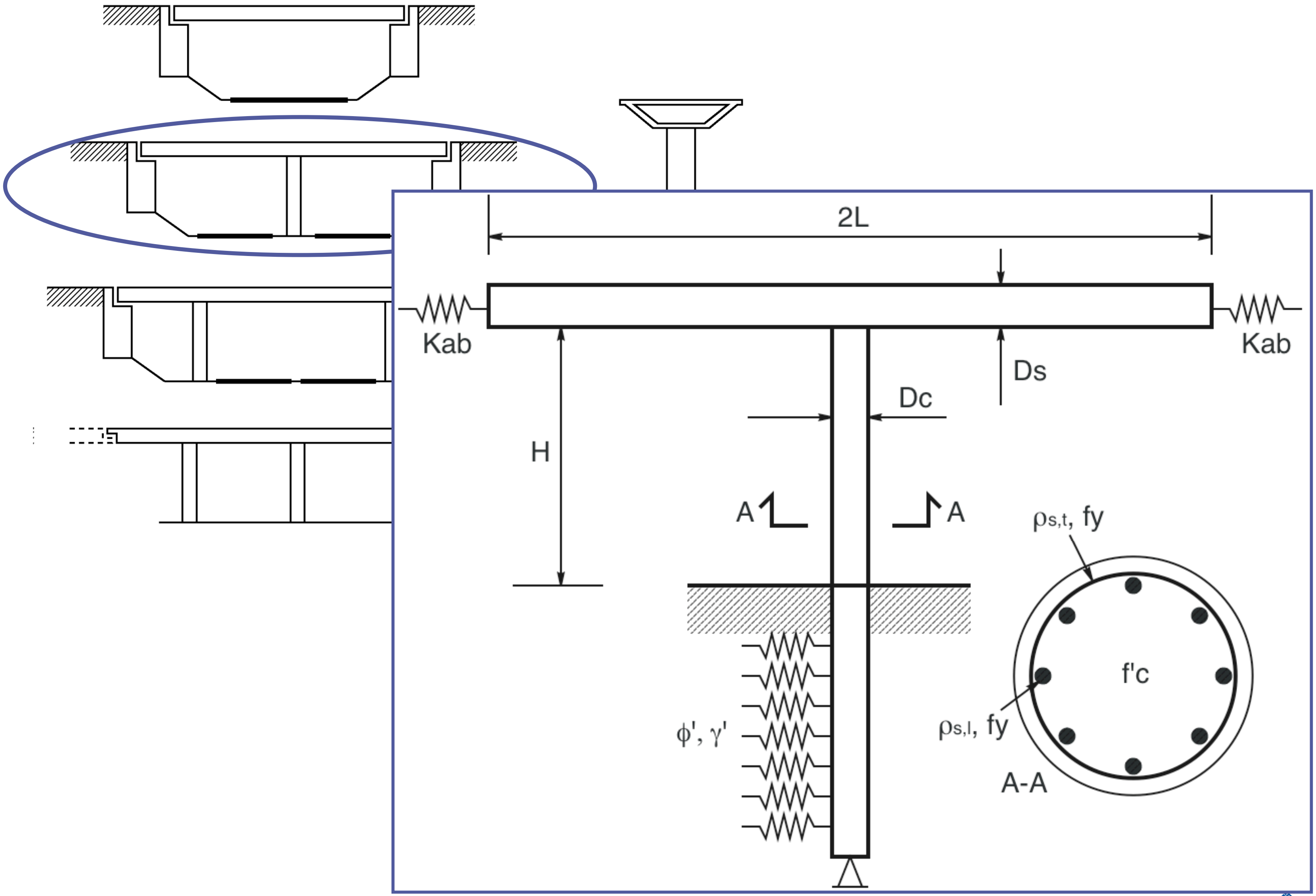
Earthquake #1 (50% in 50 years)



Earthquake #2 (2% in 50 years)

- Non-linear response at 2% in 50 year hazard level

Parameterized Caltrans Bridge Models



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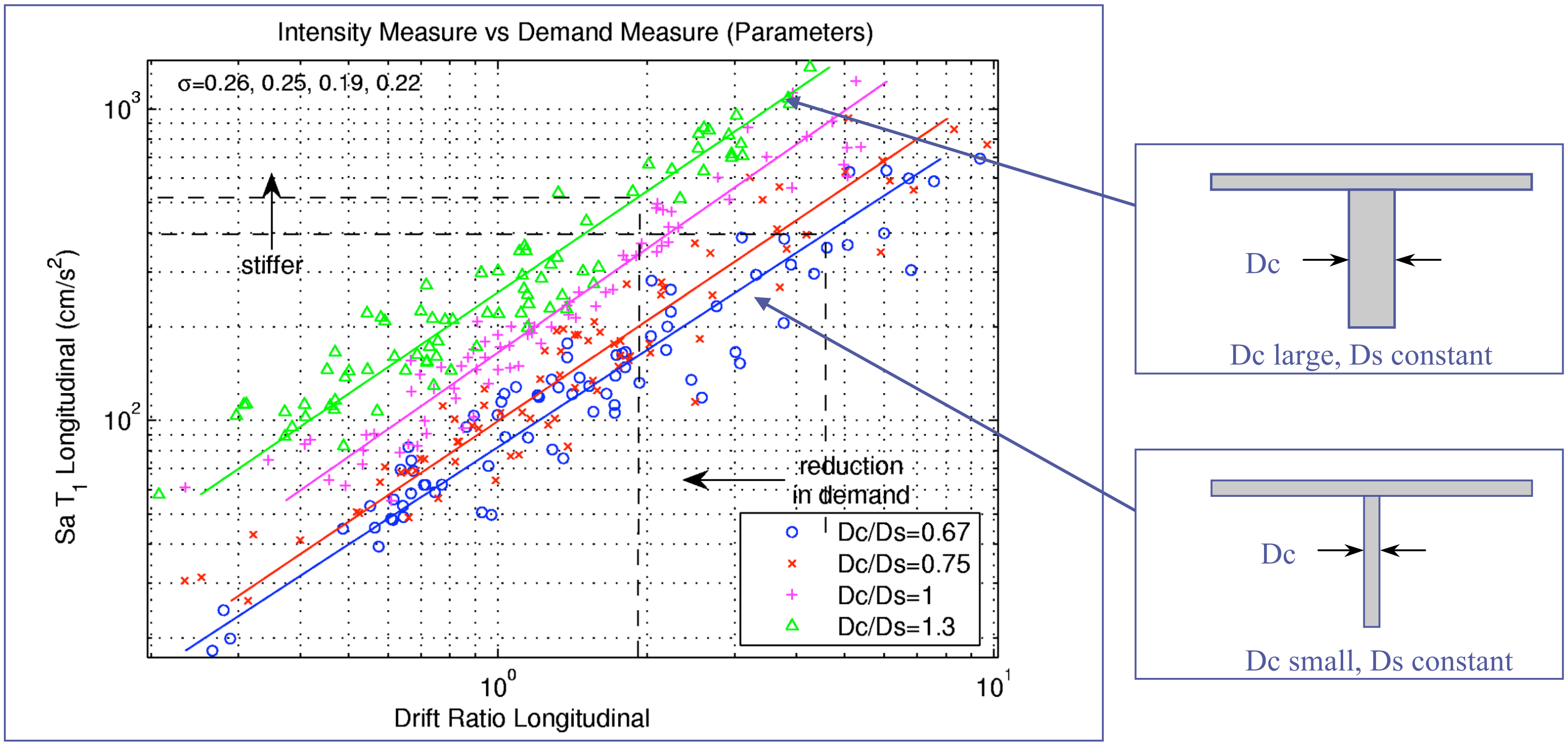
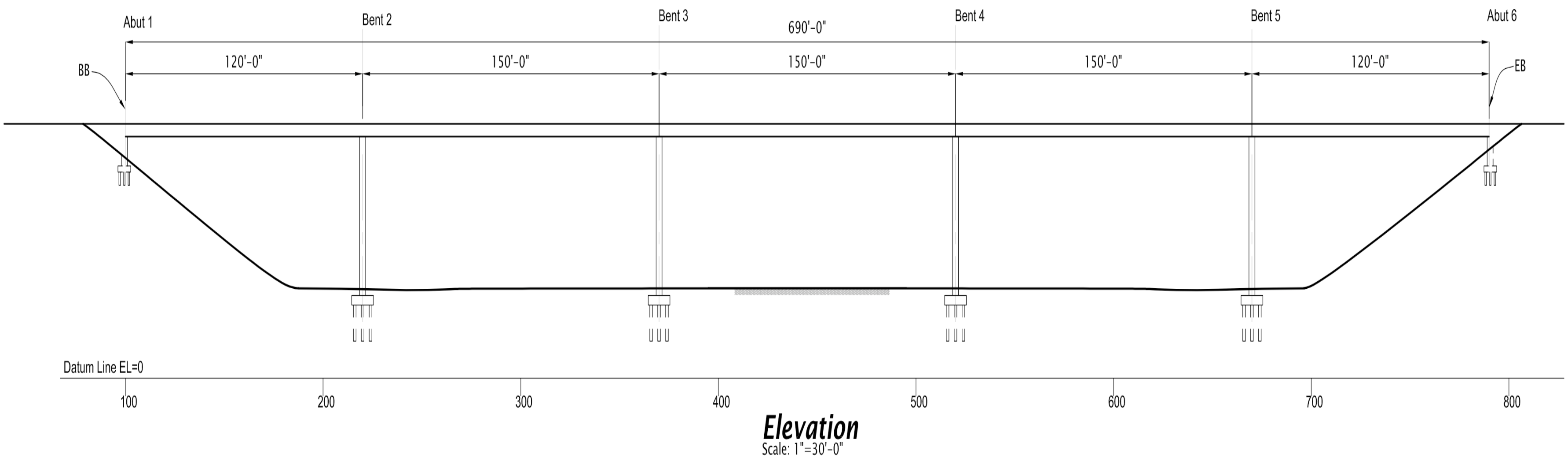
Parameterized Caltrans Bridge Models



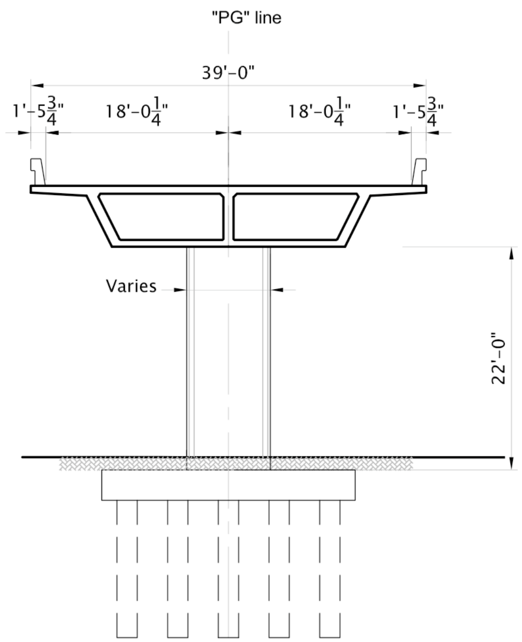
- Variation of single-bent bridge column diameter (Dc)

Caltrans Overpass Testbed

- Bridge characteristics
  - CIP, post-tensioned box girder
  - Deck 39 ft wide, 6 ft deep
  - Single column bents
  - Span lengths 120-150x3-120 ft

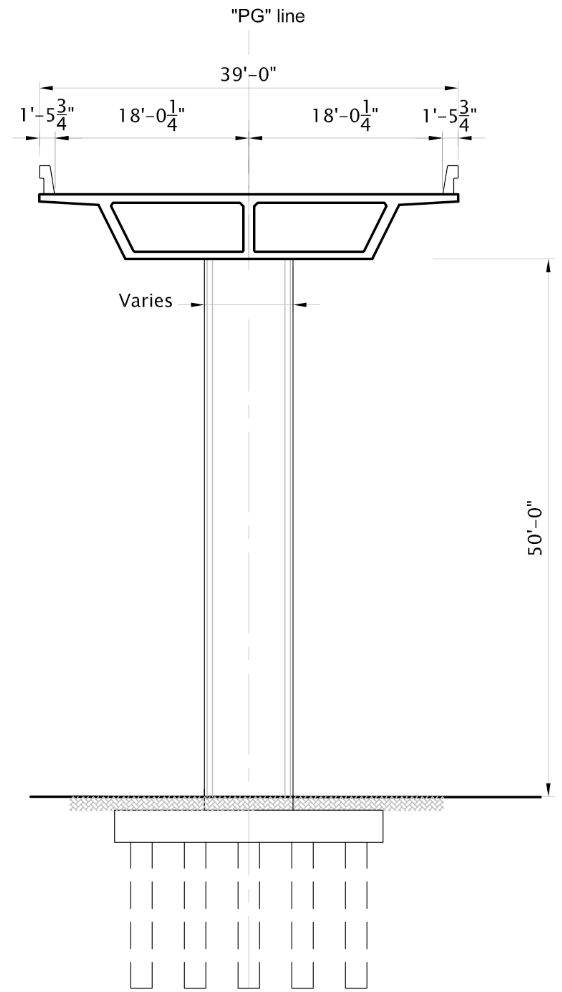


Testbed Bents



Typical Section
Scale: 1"=10'-0"

- Type 1

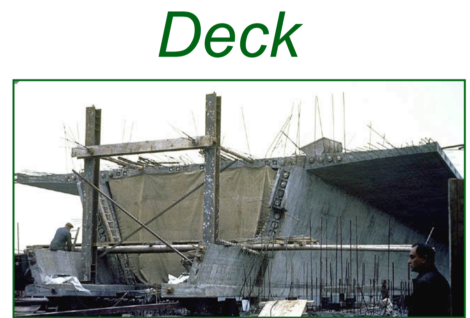


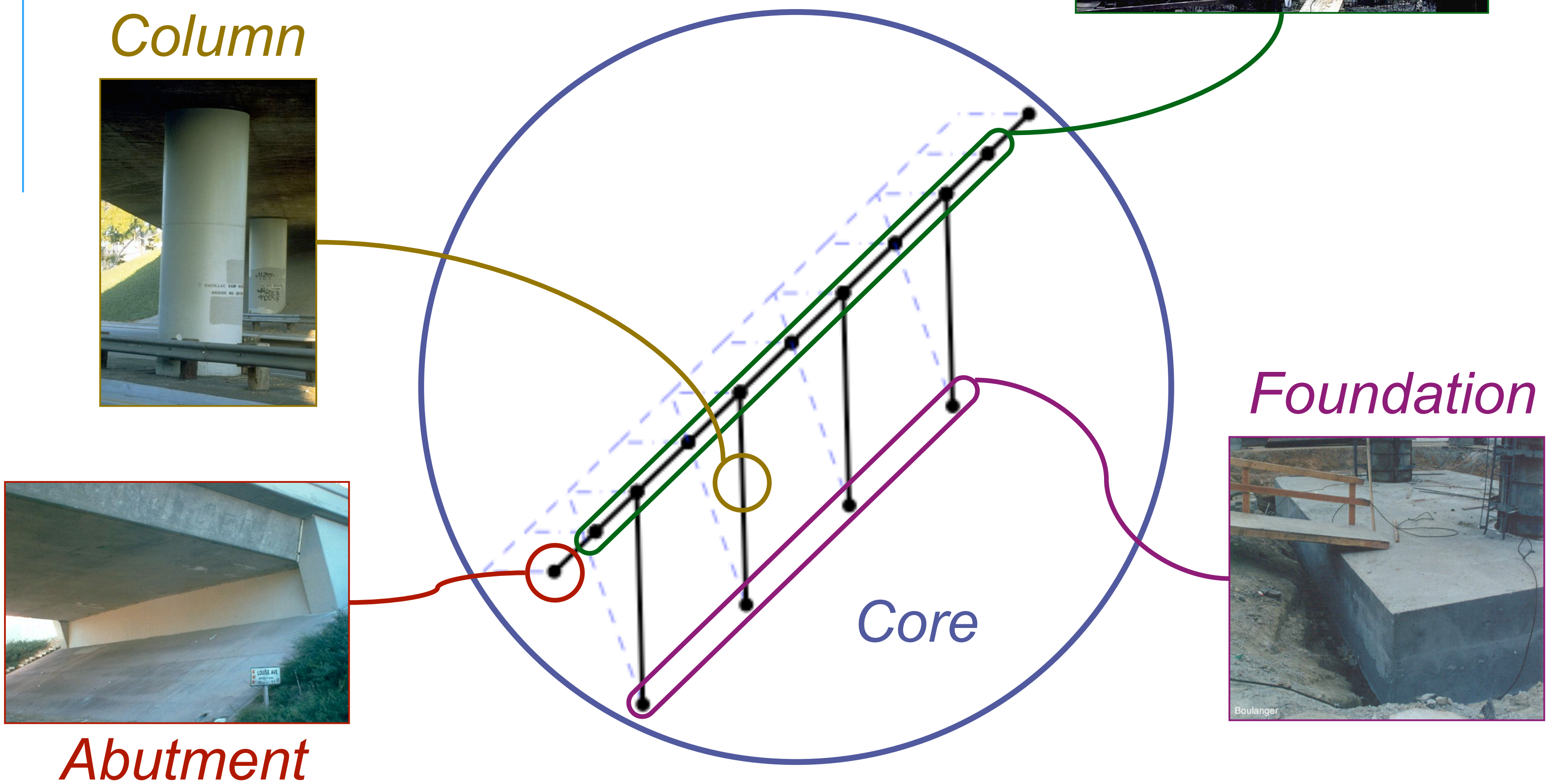
Typical Section
Scale: 1"=10'-0"

- Type 11

Bridge Model

- Modular design





Bridge Model

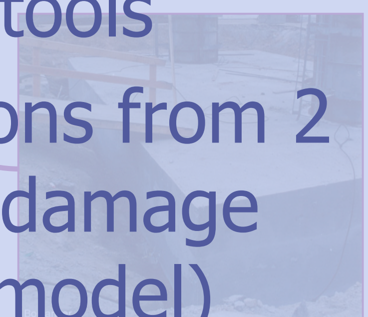
- Modular design

Deck

Column

- Allows system-level performance-based assessment for developers of individual components
- Baseline structure for comparison of results using emerging technologies/analytical tools
- Incorporates contributions from 2 previous talks (column/damage modeling & soil profile model)

Foundation



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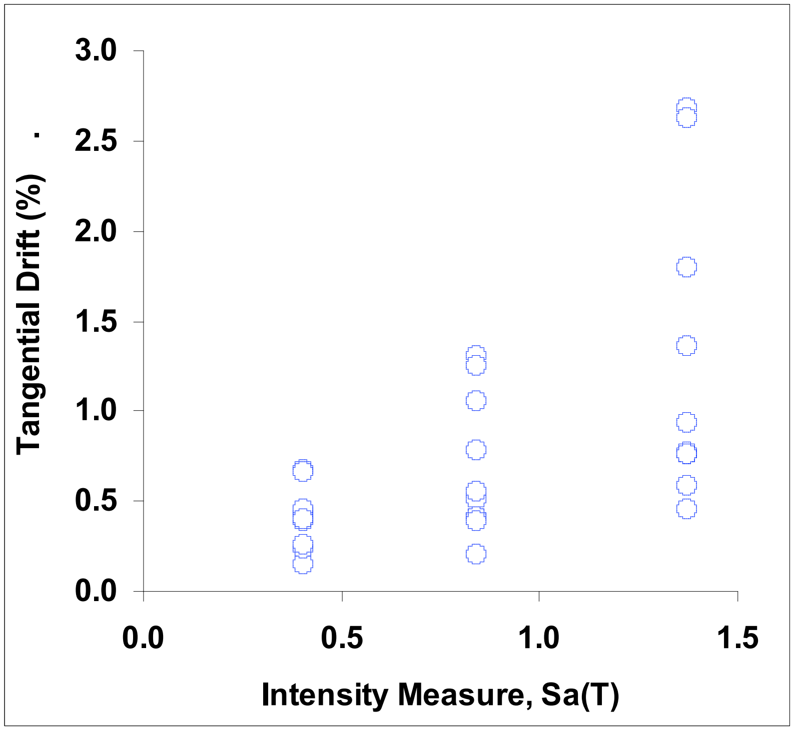
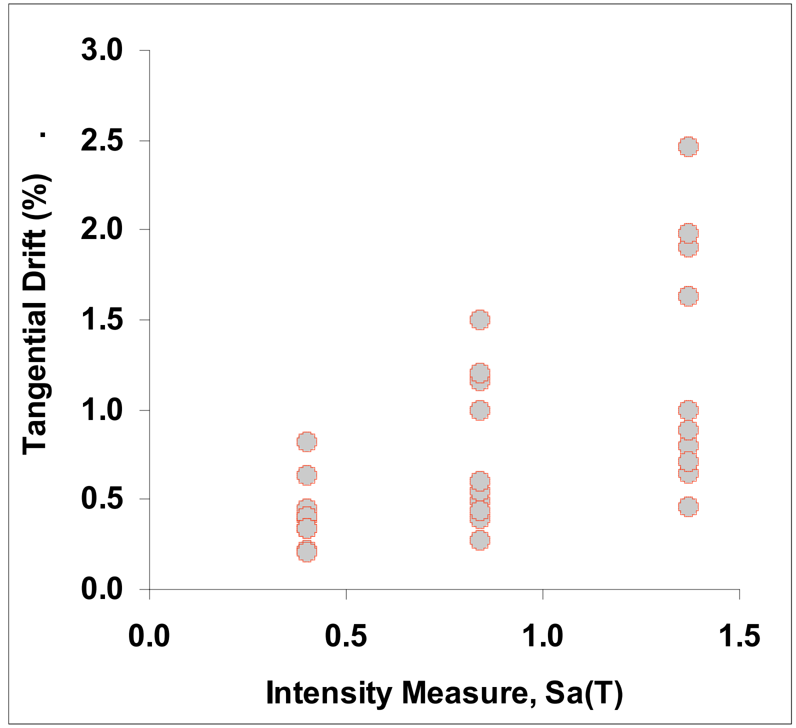
Nonlinear vs. Linear Analysis

- Advantages of nonlinear analysis
  - More accurate demands at higher intensities
  - More accurate intermediate and local response measures (moment, curvature, strains)
  - More accurate bridge component response (expansion joint, abutment, soil & foundation)
  - Strength and stiffness degradation
  - Residual displacement
  - Captures uncertainty due to nonlinearity of structure
- Disadvantages of nonlinear analysis
  - Computationally costly
  - Sensitive to modeling choices
  - May be unnecessary at lower intensities
  - May be unnecessary for global response measures

I-880: Linear vs. Nonlinear Demands

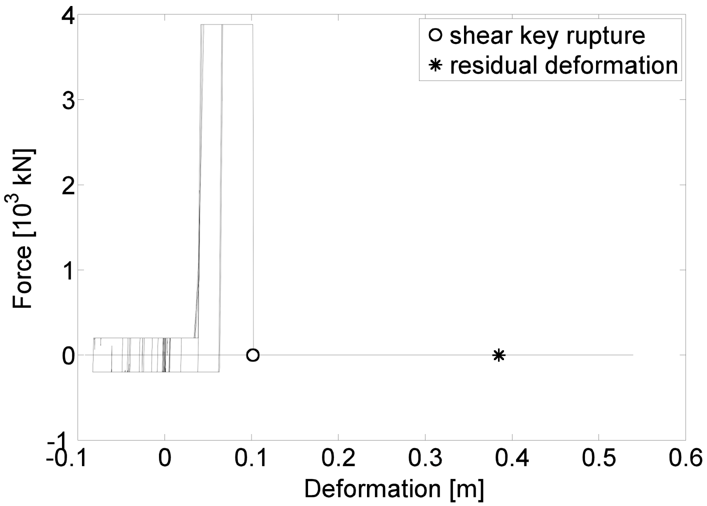


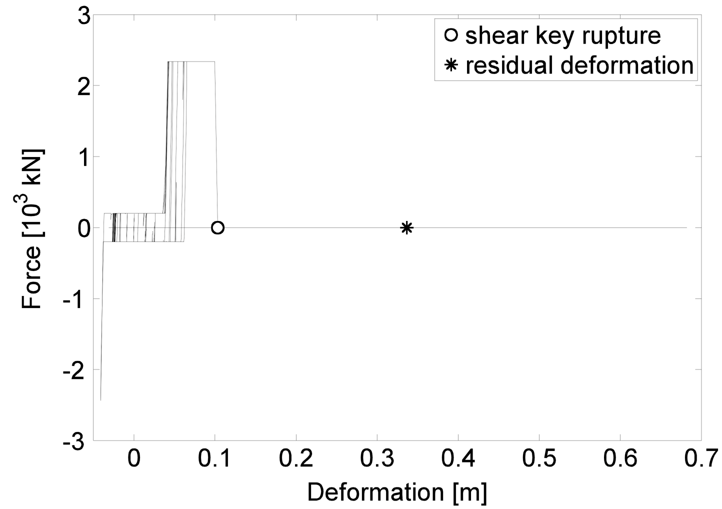
Inelastic Model



Elastic Model

HBB: Shear Key Response

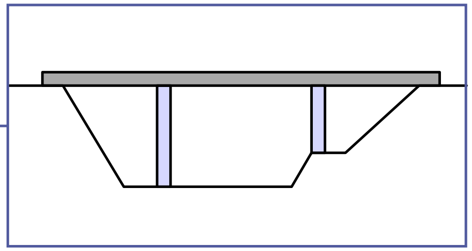


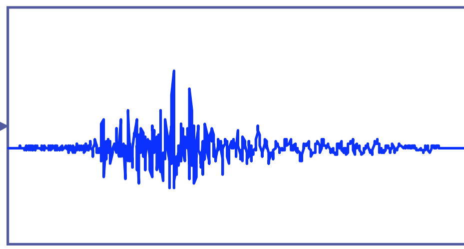


Force-deformation responses of shear keys at (a) left abutment, and (b) right interior expansion joint, during Earthquake #2

Bridge Function: Aftershock Fragility

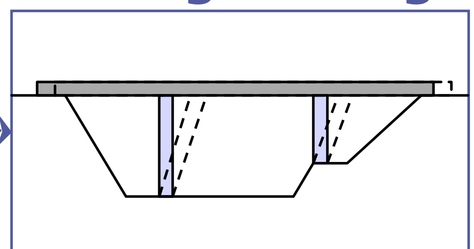
Original bridge

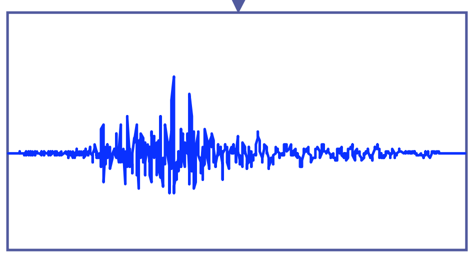




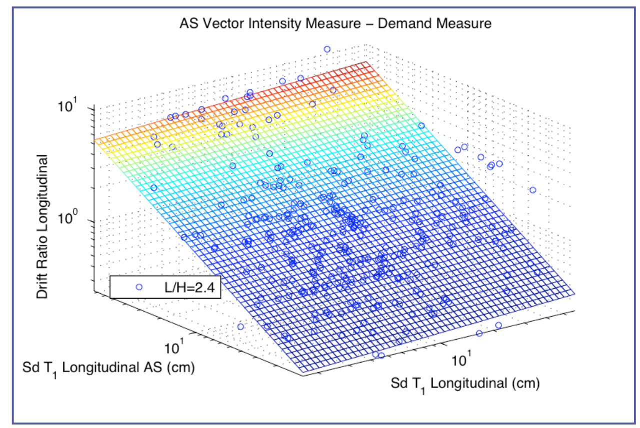
First shock

Damaged bridge





Aftershock



Probability of sustaining an aftershock given the magnitude of the first shock

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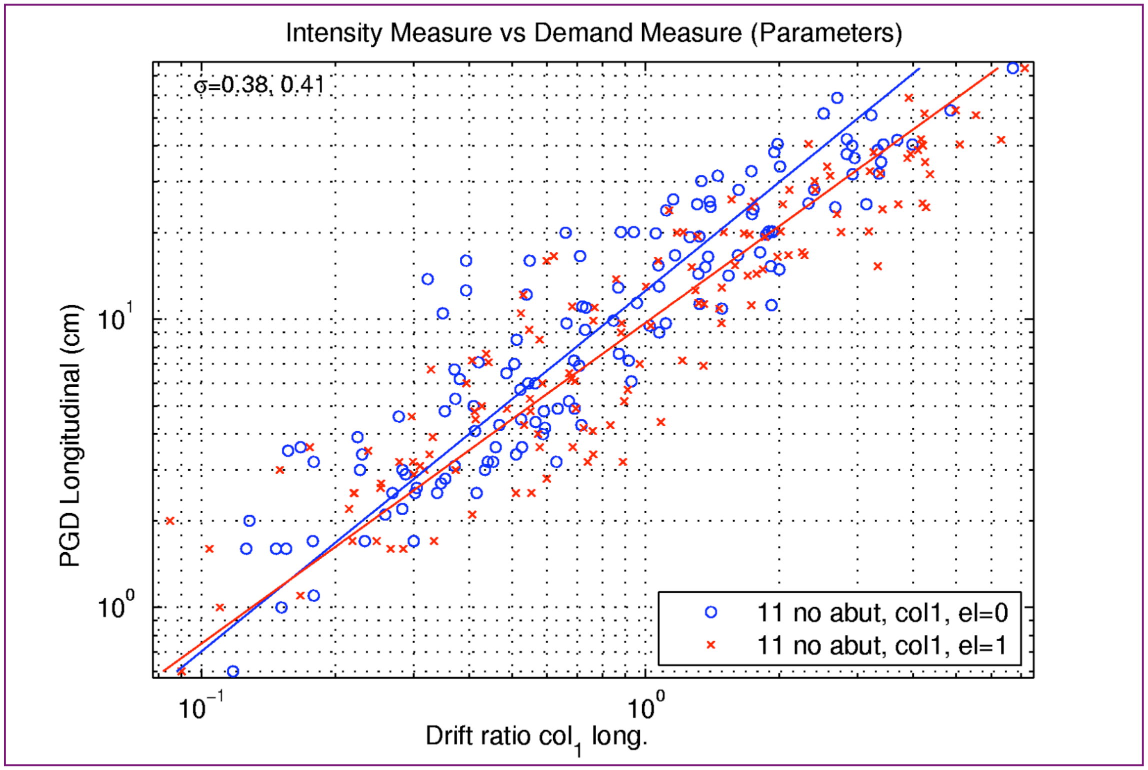
Linear vs. Nonlinear Demands

- Testbed bridge



- Type 11, column 1, roller abutment, fixed base

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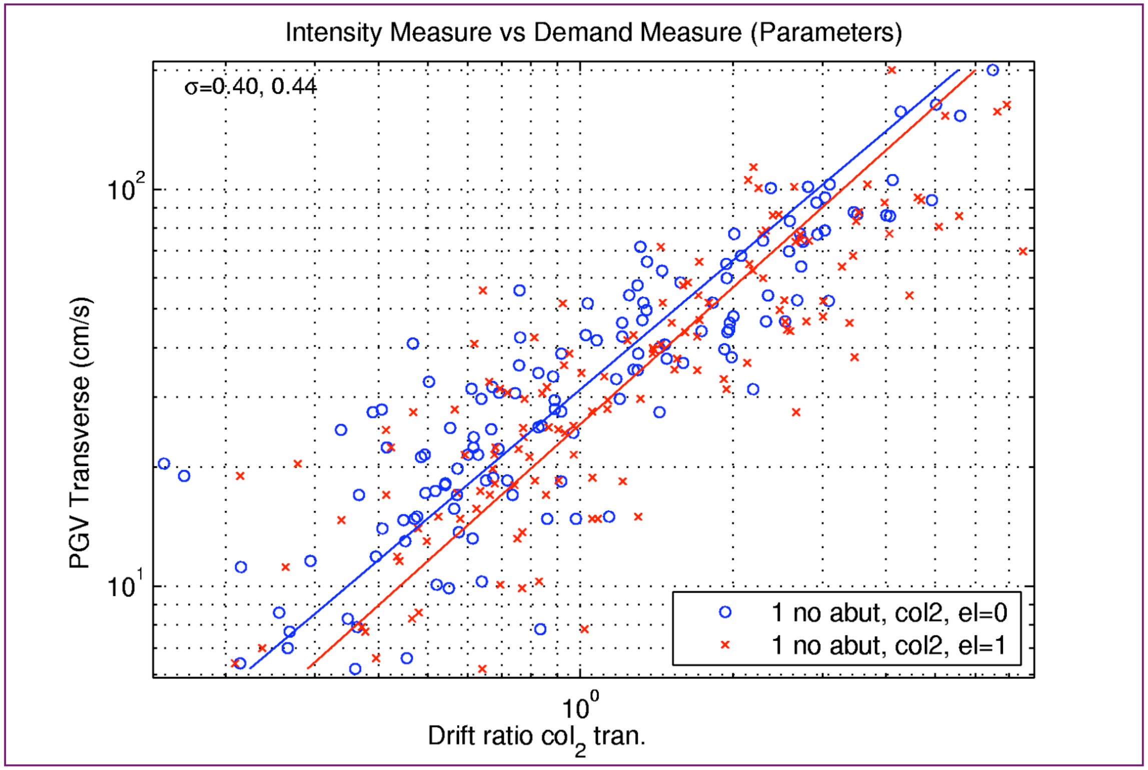
Linear vs. Nonlinear Demands

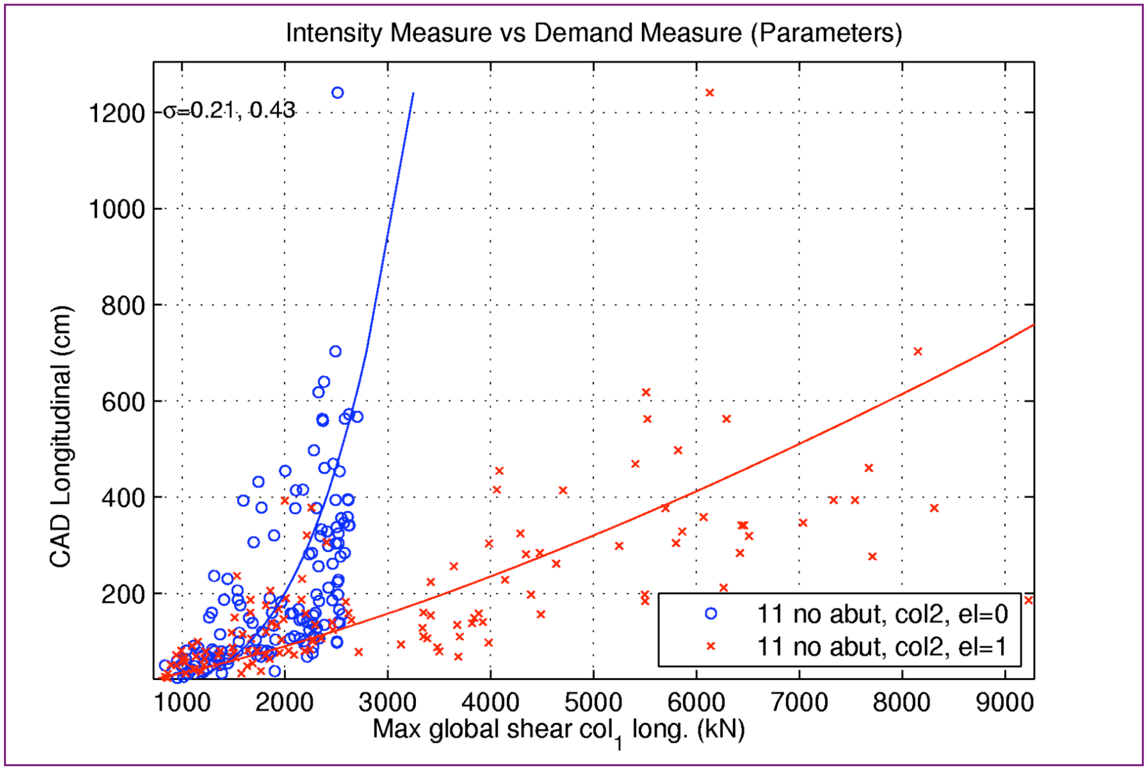
- Testbed bridge



- Type 1, column 2, roller abutment, fixed base

Linear vs. Nonlinear Demands

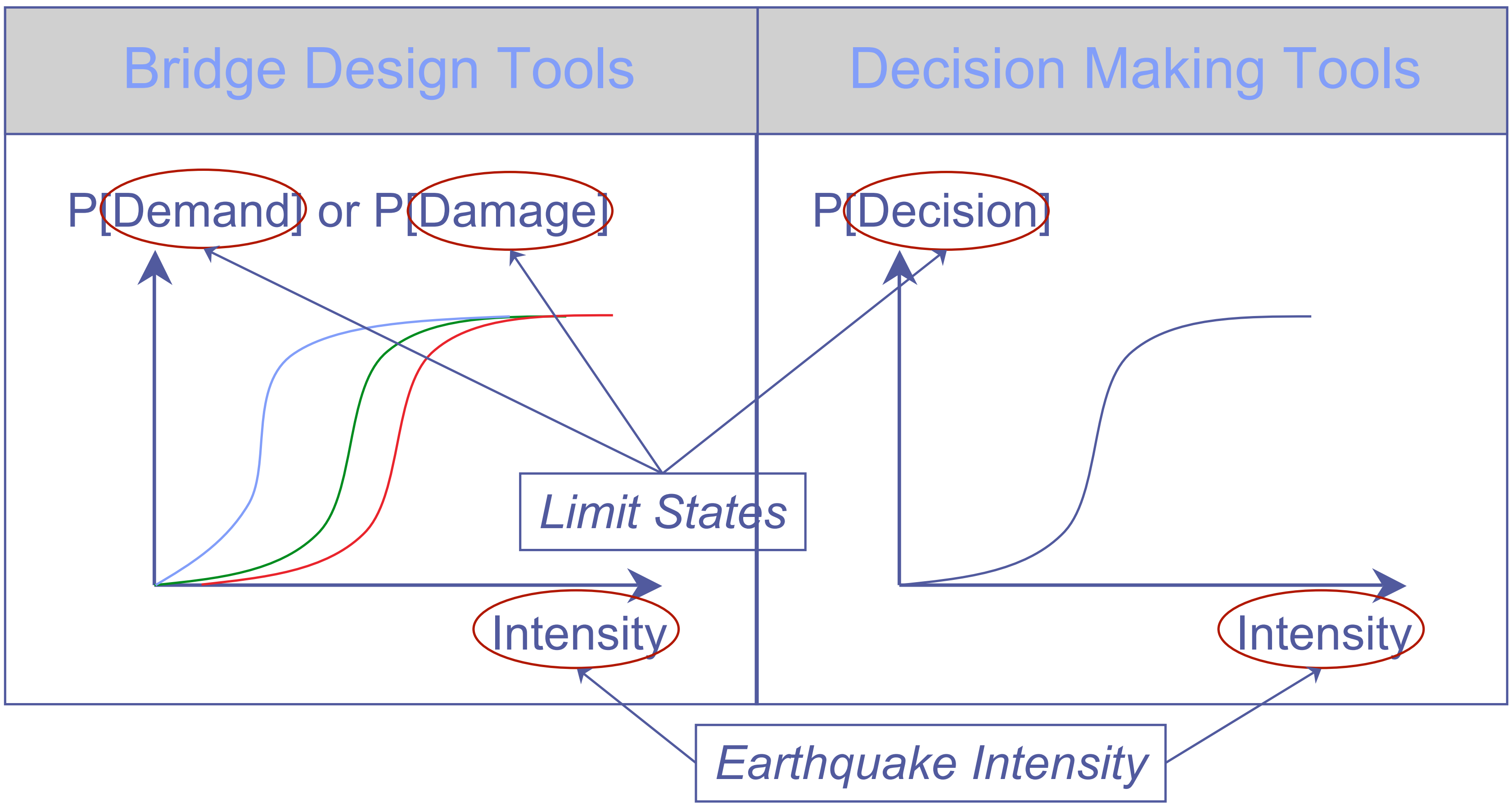
◆ Intermediate EDPs



◆ Type 11, column 2, roller abutment, fixed base

Bridge Fragilities

- Fragility - conditional probability of exceeding a limit state, given measure of intensity



PEER Center Framework

- Divide and Conquer!

$$P\left(DV > dv^{LS} \mid IM = im\right) = \iint G_{DV|DM}\left(dv^{LS} \mid dm\right) \cdot \left|dG_{DM|EDP}\left(dm \mid edp\right)\right| \cdot \left|dG_{EDP|IM}\left(edp \mid im\right)\right|$$

- Interim models:
  - Demand
  - Damage
  - Decision

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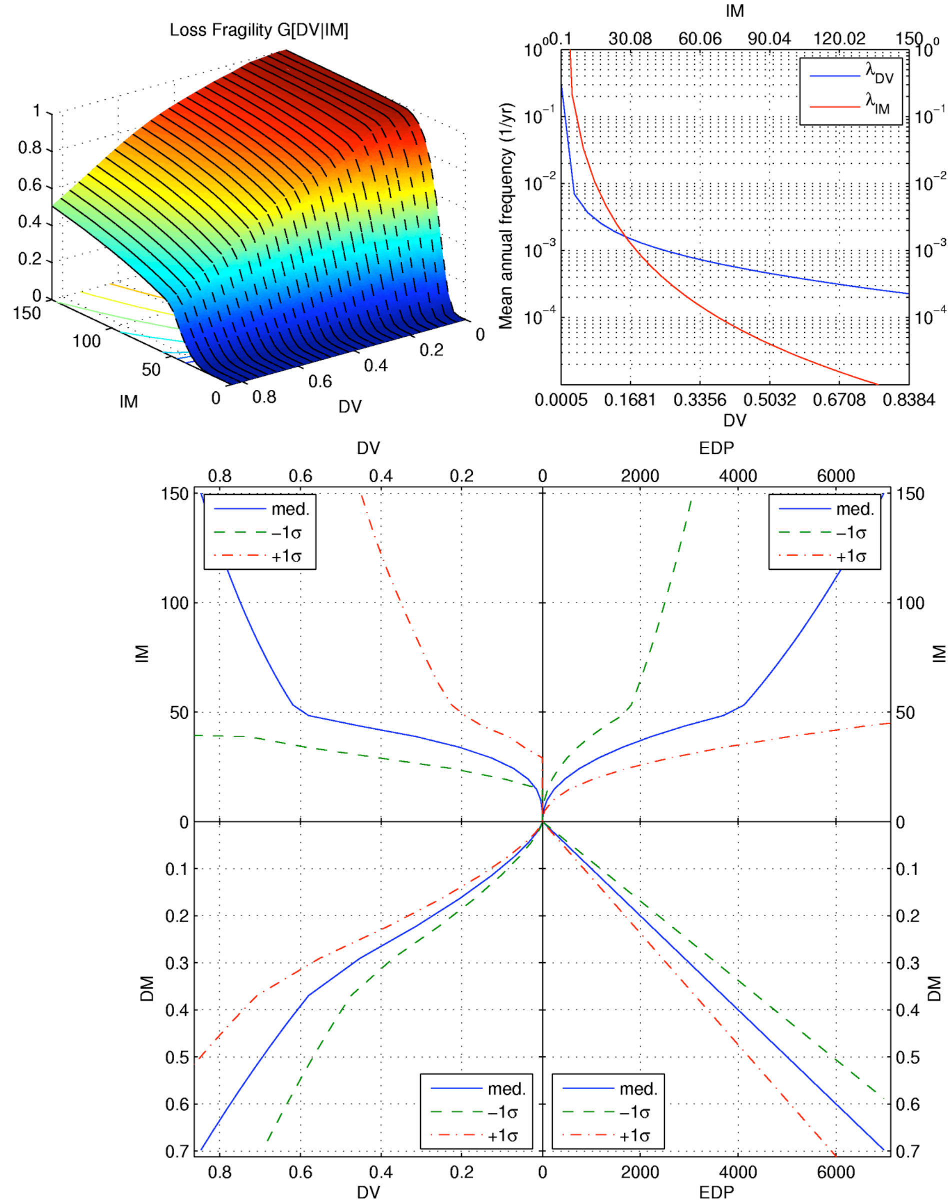
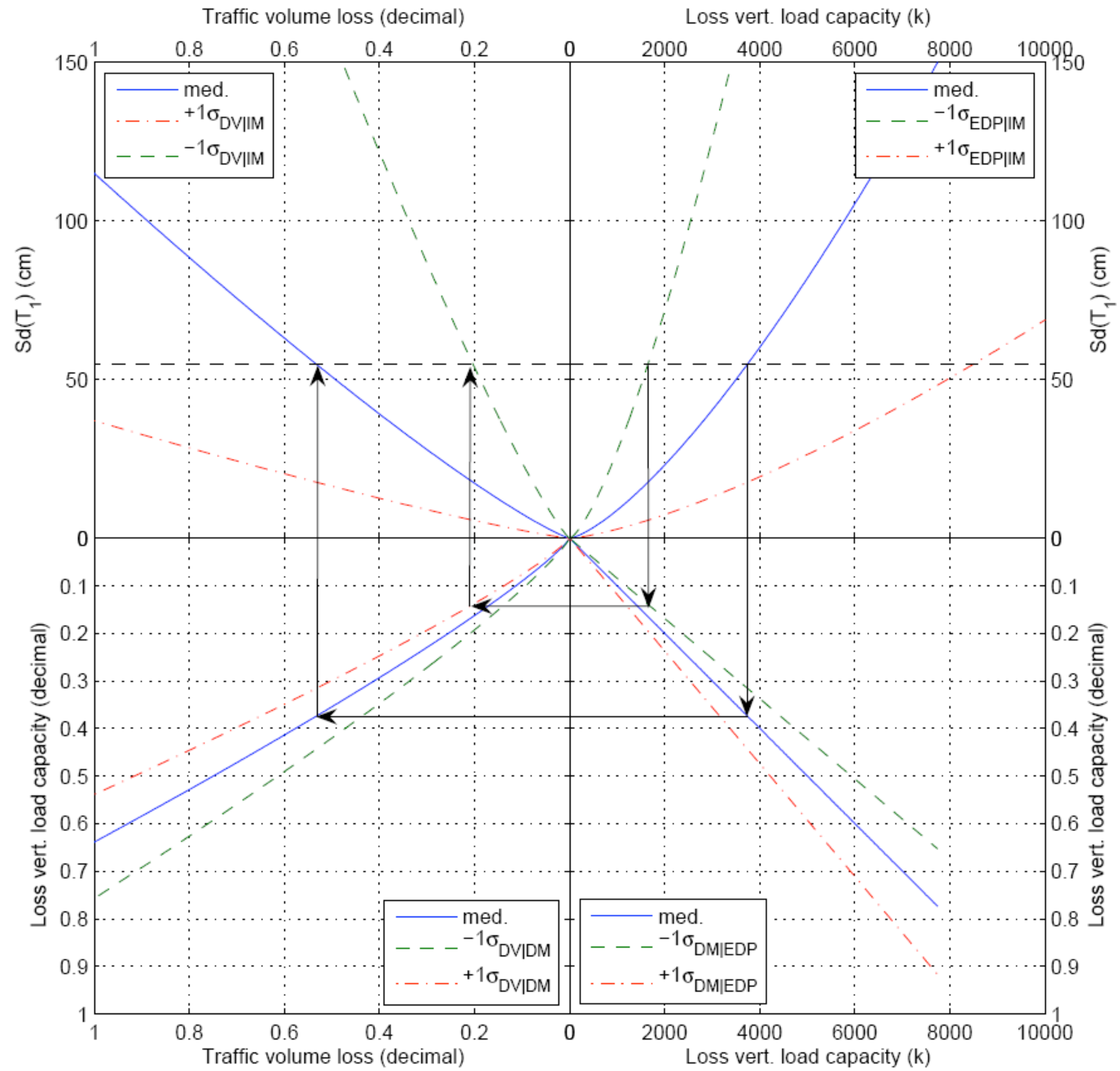
Computing Decision Fragility

- Given the interim models, Matlab tool computes the conditional probability of failure (median, dispersion)
- Assumptions required



Computing Decision Fragility

- Use a graphical method, Fourway, to obtain the conditional probability of failure (median and dispersion)
- Approximate, but no assumptions required



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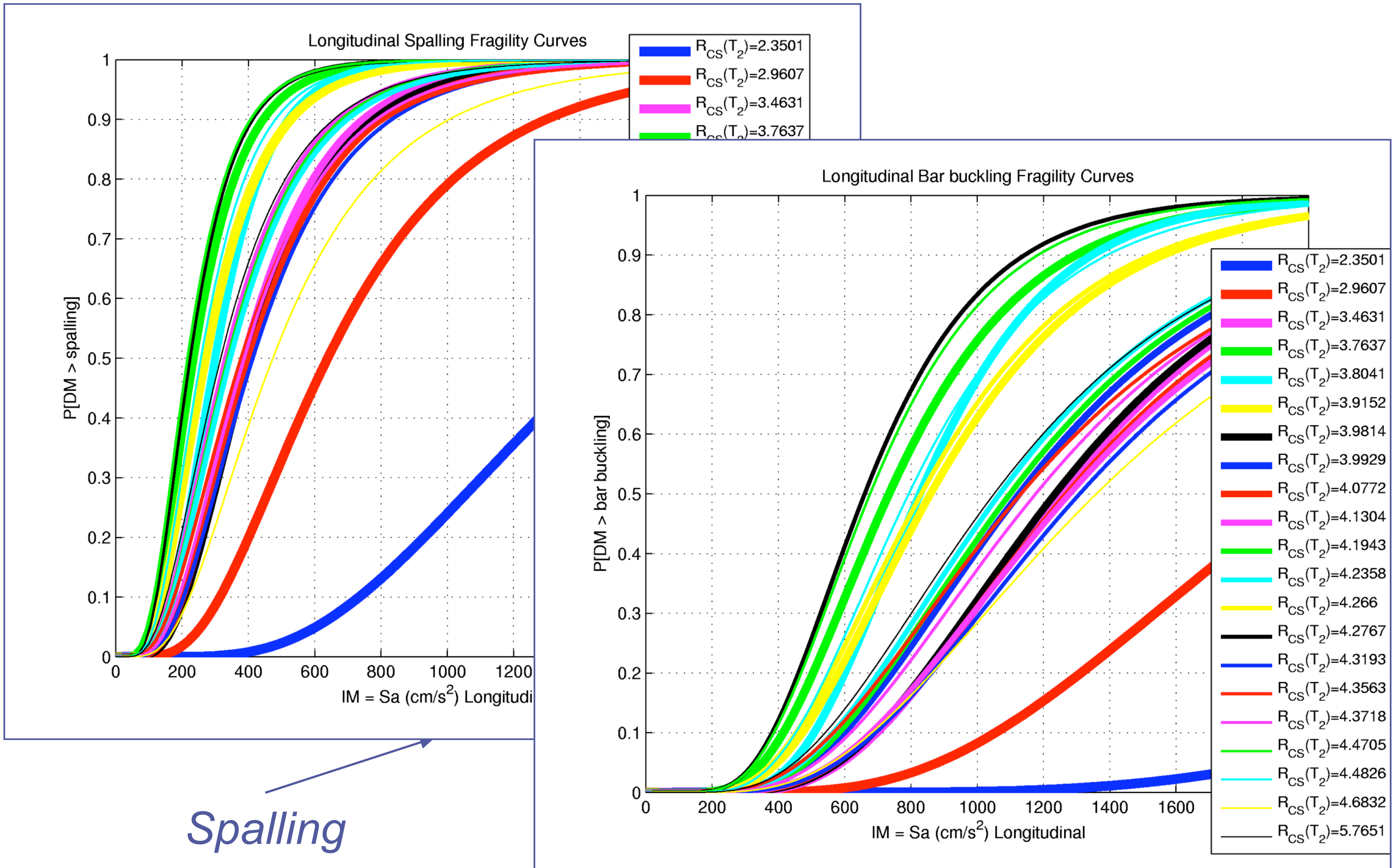
Families of Damage Fragility Curves



Spalling

Bar buckling

Kunnath

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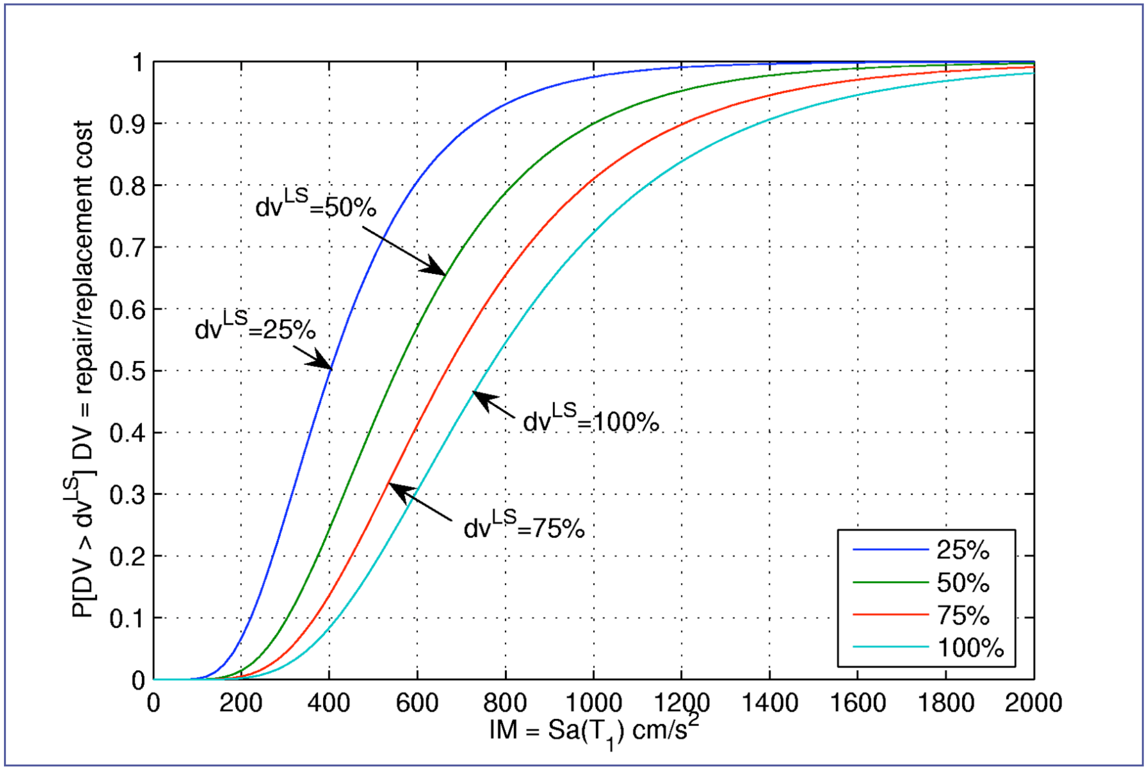
Decision fragility curves



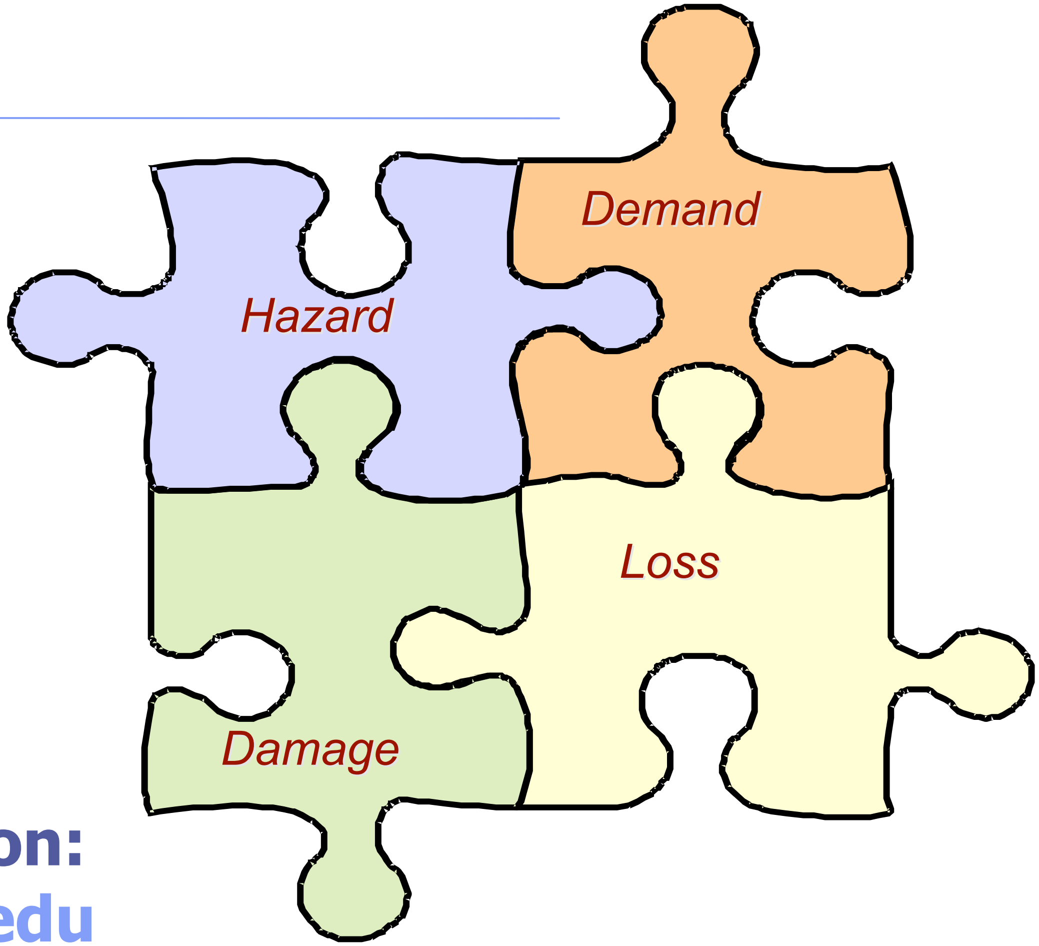
- Repair cost ratio (RCR)

The Next Steps

- Document ongoing work
- Nonlinear vs. linear analysis
  - More detailed study of nonlinear vs. linear analysis in the presence of abutments, soil, performance-enhanced elements, etc. is needed
  - Under many restrictions, linear analysis may provide sufficiently accurate estimates of mean global EDP
- How to improve fragilities?
  - More repair cost data
  - Better damage data for bridge components other than columns
  - Calibrated models for other bridge components
  - Better estimate of damage due to geotechnical failure modes: SSI analyses
  - Enhanced columns designs (rocking, jackets, HPFRC)

Thank You!

Discussion



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